ANIMAL PHYSIOLOGY

FOR SCHOOLS

J. Milner Fothergill M. D.

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ANIMAL PHYSIOLOGY

FOR SCHOOLS

IN THREE PARTS COMPLETE

BY

J. MILNER FOTHERGILL, M.D.

"What a piece of work is man."

LONDON
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1881

he Athenæum+ has called this little
work "rigmarole". Despite this
nsolicited abuse – the spume of ig-
norance, conceit, and malice
lended, the demand for it tells
ta it meets a want and fills
vacant niche in the Educational
Course.

he review (July 23rd 1881) was simple
ndecent, and an ~~outrage~~ blot on respec-
able journalism: indeed it is matter
or surprise that the Rev. M. Maccol
llowed it to appear at all.

A. Beatrice K. Milne-Fothergill

PREFACE.

SOME acquaintance with animal physiology is indispensable to the present scheme of school education. Instead of a series of facts arranged in dry anatomical terms and technical language, the attempt is here made to "tell the story" of the build of the body; of the action of the muscles; of the process of digestion, of the circulation and the respiration; of the construction and functions of the nervous system—in the simplest language possible: not to satisfy, but to incite the youthful reader to wish to know more of physiology,—of the different organs of his body and their functions.

Originally designed to meet the requirements of the Education Department, for Elementary Schools, this little work was published in three separate parts. The approval expressed of it by the press has led to its publication in a complete form. Instead of attempting to bring the parts to a uniform level, it has been thought desirable to permit the original arrangement to remain.

To the Memory

OF

JANE AGNES CHESSAR,

TEACHER,

THIS LITTLE WORK IS DEDICATED

BY HER FRIEND

THE AUTHOR.

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By J. MILNER FOTHERGILL, M.D.,

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ANIMAL PHYSIOLOGY.

PART I.

CHAPTER I.

ANIMAL LIFE.

EVERY child has seen a steam-engine, with its tender full of coals, standing ready to take away its train of carriages with the passengers inside. The force needed to drag this weight swiftly along does not lie in the heavy iron work of the engine, but in the coals in the tender. By the combustion, or burning of the coals, heat is produced, and this changes the water in the boiler into steam; the piston, cranks, and wheels of the engine are a contrivance for turning the power of steam into motion. Thus the steam is the motive power which moves the train; this motive power depends on the heat given by the burning coals.

Now an animal, especially one with a backbone and possessed of power of motion, is in some things very like a railway engine. The bones and muscles of its body answer to the machinery of the locomotive; but the motive power itself is dependent on the food we eat. Our food is to us what fuel is to the engine. Burning is sometimes called "oxidation," because when anything is burned a great part of it is "oxidised," that is united with the gas called oxygen in the air. Oxidation may go on quickly, or slowly. It goes on quickly in the engine furnace, and slowly in our blood; as will afterwards be shown in succeeding lessons. Meantime it is enough to remember this: that by the *oxidation* of the fuel-food of the body the force needed for motion is produced; just as in the case of the steam-engine. The oxidation of the fuel of the engine produces heat and motion. So the oxidation of our "fuel-food" produces the body-heat and motion.

Every child must have noticed for himself that his body is warm. Especially in cold weather he must have observed that, while stone, and iron, and water become as cold as the surrounding air, the human body remains warm. The toes and fingers, however, may feel chilly because the warm blood from the interior of its body gets cool before it reaches so far. How comes the blood to be warm? It is warmed by the burning or oxidation of the food taken into the body. The chief distinction to be noted just now between the animal and vegetable world is this: animals possess heat and motion, vegetables possess neither. Vegetables have of themselves no power of moving from place to place. A forest of trees may be swayed by a strong wind, or a field of corn may rustle in a breeze; but there is no voluntary motion. Yet the vegetable world stores up that food which renders motion in animals possible. So the fuel of the locomotive consists of the remains of what once was vegetable life; coal-fields are the petrified forests of a far-away bygone time.

This, then, is the chief difference to be remembered between the animal and the vegetable world. Both possess life. Both grow, and in time die. Extremes of heat and cold alike kill both. But in the animal there exists something more than mere life, in its lowest sense. The animal, except very lowly forms, can move at will. What that will is, it is not necessary to describe here. If the child sees a book on a shelf within his reach and wishes to read it, he can walk to the place, stretch out his arm, take down the book, and read it. No vegetable can do anything that needs movement from its place. For the child to do this, several portions of the body are put in action. The mind wills to have the book, the brain then sets the muscles in motion by means of the nerves, and the muscles move the bones of the legs and arms; the legs take the child to the book, and the arm reaches the book; the legs then take the child to his former place.

Now what are the muscles? If we look at the carcases of sheep hung up outside a butcher's shop we see three things: (1) red flesh, which is muscle; (2) the white fat; and (3) the hard bone.

It is the red flesh which in life moves the bones. The nerves are white cords running from the brain and spinal marrow to the muscles; but they are not visible without careful search, and we must leave them for future lessons.

When any one is struck with a rod, or touched with a hot wire, or pricked with a pin, pain is produced. How is this? We are covered with a skin having nerves scattered through it all, leading to the brain. These nerves convey the feeling of pain. If it were not for this sensitive outside covering to protect the structures beneath, we should constantly be injuring ourselves. But the pain caused by injury to the skin makes us careful; and so the structures beneath are watched over and protected.

An animal, then, can feel pain, besides possessing heat and the power of motion; and in that respect also is different from a vegetable. It has a general sensitive or feeling surface, the skin; beyond this, too, it has special sensitive parts, as the fingers' ends, which possess what is called "the sense of touch." By these we can examine things around us, and ascertain for instance if they are hot or cold; a matter the eye cannot tell.

To protect this skin from the effects of cold it is covered with feathers in birds, with fur or hair in animals with four feet; while in man the hair is chiefly on the head, so he covers himself with clothes. Clothes protect the skin from injury, and keep the body from becoming cold. In cold climates to protect himself from the chilly air man clothes himself warmly in the skins of animals; in hot countries he goes about almost naked—clothes, such as they are, being worn only for the purposes of decency.

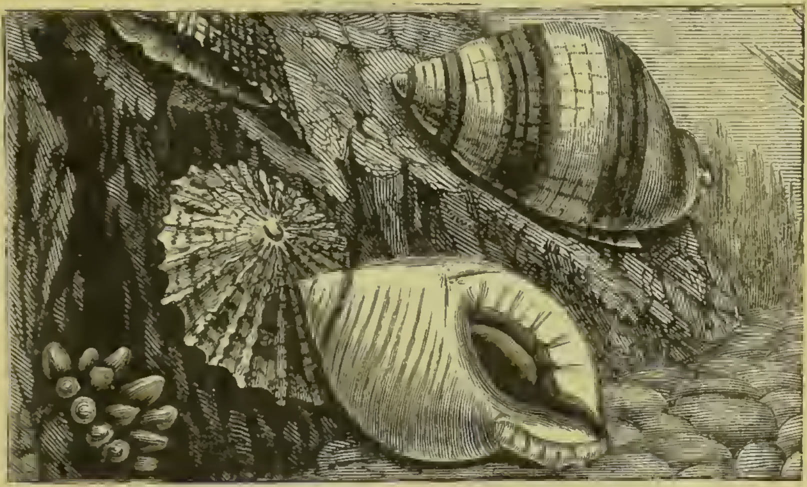
A steam-engine requires regularly repeated supplies of fuel; so man ought to have regular meals. Then the steam-engine wears out, and needs repair from time to time. In the body self-repair is constantly taking place in all its parts in the red flesh (muscle), the brain and nervous system, in the blood vessels and the blood itself, in the bones, and in the skin; for this purpose "tissue-food" is required as well as "fuel-food." The different elements of the body, such as bones, flesh, skin, and nerves, are called *tissues;* and "tissue-food" means food which can be turned into such elements of the body. What are the special properties of "tissue-food" as compared to "fuel-food" we shall see further on.

CHAPTER II.

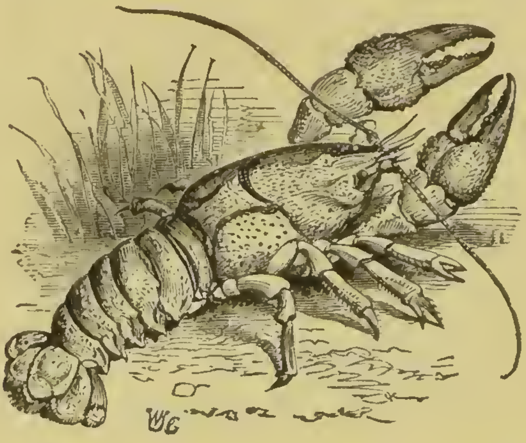
THE ANIMAL WORLD.

TO understand the build of the human body we must first think of animals in general. Suppose we could see, as in the pictures of a magic lantern, all the different animals that are or have been in the world. And suppose also that the pictures were "dissolving views," in which one kind of animal should be gradually changed into another. We must have them arranged in proper order; beginning from the simplest and lowest, and rising little by little up to man. Then the magic lantern would show us something like what follows here.

The lowest form of animal life is a speck of jelly, in which the tiny particle of food is seen to dissolve, and disappear. The next is a bottle-like creature, in the hollow of which food is digested. A step higher is a tube, which can be turned inside out without material injury to the creature. This tube is the alimentary or food canal. It forms the whole of this simple animal; but is only a part of those that come after. Gradually, on this central canal, a liver is developed. For long the body is a soft mass in a shell, as seen in the periwinkle, the whelk, and the snail. Or its shell is in two halves, as in the mussel and the oyster.



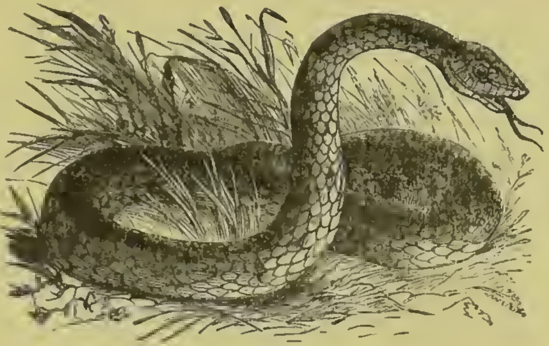
Gradually the outer covering shows a greater number of parts, and is built up of segments, or separate pieces, as seen in the lobster, the shrimp, and the ant. In fact the animals we now see begin to have a skeleton; only it is an outside skeleton, not an inside one like ours. The bones of these creatures are spread out over the soft internal organs; and to admit of movement this outside skeleton, or shell, is in many separate pieces. Limbs have become developed. The animal no longer lives on such food as drifts past it; it can now move in search of food. Hitherto animals have been fixed; attached to the bottom of the sea. But now they can move about, crawling slowly as a rule, though the shrimp is very active. The *articulata*, as these jointed animals are called, can move in search of food, or escape from another animal pursuing them for food. Their limbs are protected by an outer skeleton, as seen in the claws of the lobster and the crab.



Flies, bees, also fleas, and other unpleasant body vermin, belong to the class of articulata.

Then we come to animals with a backbone. Now an inside skeleton is developed. There is a framework of bones, moved by muscles outside; as

seen in fishes, as the haddock, the codfish, and the flounder. The tail is the chief instrument of motion; but there are also fins which aid the action of the tail, both in movement and in direction. When the animal can walk these fins become legs. Thus we get to the *reptiles*, as the tortoise and the turtle. The serpents have not got any legs, yet they possess considerable power of movement.

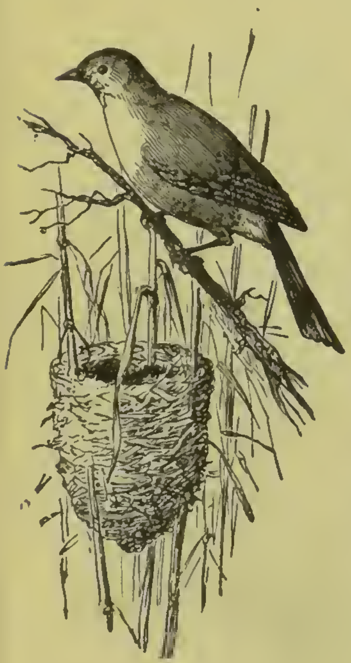


Once, long ages ago, there were very large reptiles;

now they are comparatively small, the alligator being the largest reptile now living. Then we have the frog, which starts in life as a tadpole, with a tail by which it moves in the water. As it grows the tail disappears, and legs are developed. Thus the tail vanishes as the great moving power, and legs take its place. All this time the animal has been "cold-blooded," that is, it has been nearly of the same heat as the surrounding air or water. Now come the "warm-blooded animals." Hitherto the food has chiefly been required for the growth of the tissues ; now the animal requires "fuel-food" to maintain its body-temperature. It requires more food, and this needs greater activity ; so it has legs which move rapidly. During this time the stomach and parts connected

with it have undergone great changes; while the mouth, besides being used for eating, has been the chief weapon of offence and defence.

Specially interesting amongst these warm-blooded animals are birds, some of which live on



the ocean, some on land; but nearly all possess the power of flight in air.

The ostrich cannot fly, but runs very fast, and its wings aid its legs. In former ages some birds now extinct, that are no longer found anywhere alive, grew to a great size, and could not fly, as the *moa*. Fishes, reptiles, the frog tribe, and birds reproduce their young by eggs.

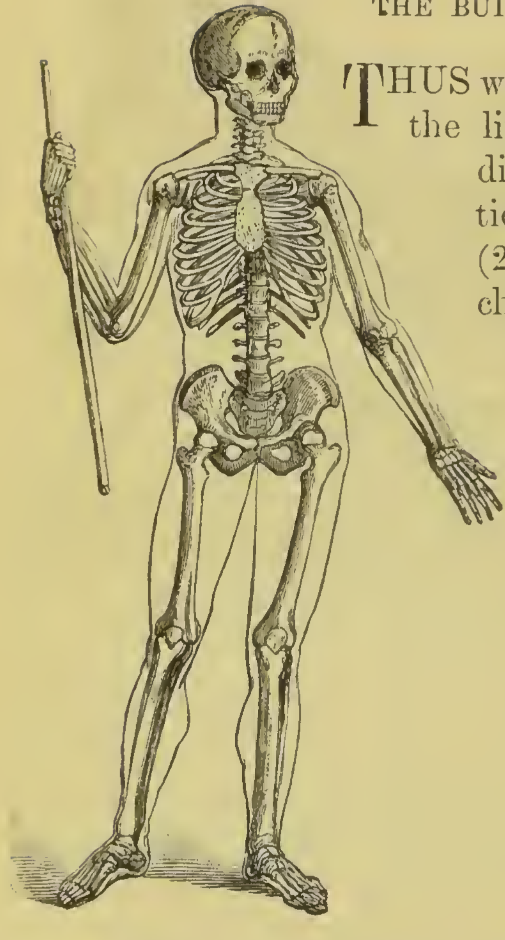
Next we come to animals which suckle their young ones, and for this purpose possess breasts. They are called *mammalia* (from *mamma*, a teat). They have a backbone on which are placed two girdles of bone—the shoulder girdle, from which come the forelegs; and the pelvic girdle, from which come the hind legs. The tail, which in fishes was the chief instrument of motion, becomes a rudder in birds, and with most mammals only an ornament, or at best a whisk to drive away flies. Still, with the mammals

which live in the sea, as the whale and seal, it serves the same purpose as in fishes. Some others, as certain kinds of monkeys and also rats, use their tails to hold by. Kangaroos make great use of their tails in springing; and even the greyhound uses the same member to strike the ground, and enable it to turn quickly. But to speak broadly, with the land mammals the tail is of little importance.

The skull has now become a very prominent organ. It is a bony globe in which the brain is encased and protected. These mammalia live on land, as the horse, the tiger, and the elephant; or in the sea, as the whale and seal; or fly in the air, as the bat; while the monkey tribe lives in trees.

CHAPTER III.

THE BUILD OF THE BODY.



THUS we have the body and the limbs. The body is divided into three sections, (1) the head, (2) the thorax, or chest, and (3) the belly. The head consists of the skull and face. The skull is a globe of bone, consisting of several bones closely united. It contains the brain proper and the little brain. The brain proper is called the *cerebrum;* the little brain the *cerebellum.* Each consists of two halves divided lengthways. The brain proper receives sensations, and calls out motion. For these ends it is in communication with the whole body by nerves. Those nerves which carry impressions to the brain are called *sensory* nerves; and by means of them we feel, see, taste, smell, and hear. When we wish to close the hand a message goes from the brain, along a *motor* nerve, to the muscles of the forearm; and they then draw in, or contract, and the fingers are closed on the palm.

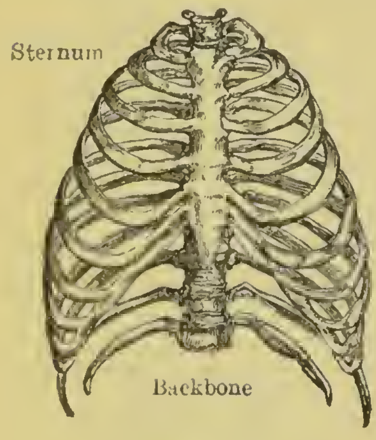
Then there is the face, consisting of the eyes, nose, mouth, and chin. It also has muscles, called "muscles of expression;" because by them we alter the expression of the face, as we smile, or frown, or look sad. The chin is formed by the jaw-bone. The bones of the head are fixed; only the jaw-bone is movable. It contains teeth, by which we chew our food. The jaw-bone grinds the lower teeth against the upper teeth, and so we chew our food. From the skull descends the *spinal chord* or marrow, by means of, a channel in the backbone. The backbone consists of a number of segments of bone, so that it will bend. These segments are called *vertebræ*. Each segment is separated from the next one by a piece of gristle. This gristle is elastic, which saves the brain from being rudely shaken in our movements; just as elastic springs to a carriage lessen the jolting

BACKBONE.

which would be felt without them. These pieces of gristle also are compressible, that is can be squeezed; else the backbone could not bend. The nerves which go to the lower limbs pass down the spine in a bundle, forming the spinal chord, or marrow. If the backbone be broken and this marrow pressed on, then all sensation and motion in the lower limbs are lost; and the person is said to be *paralysed.*

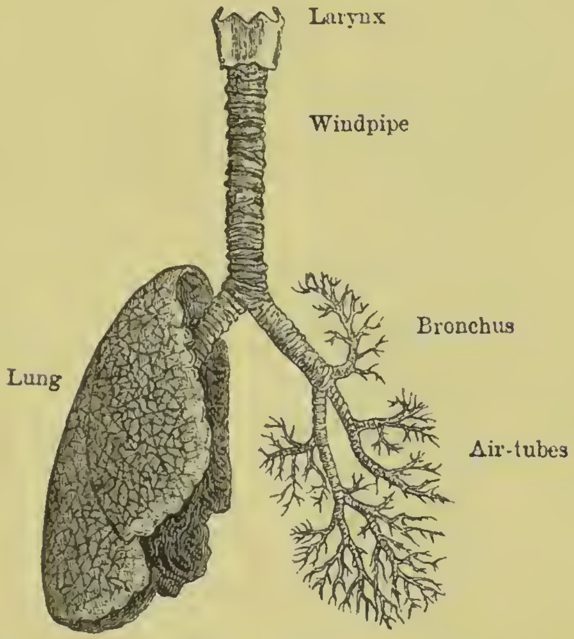
The nose is hollow; and through it the air we breathe passes to the lungs in the chest. The mouth leads to the belly by a tube called the gullet, passing right through the chest; and by this the food reaches the stomach in the belly.

The chest consists of a bony framework (thorax) formed by the ribs. If it were a solid bony casework, like the skull, we could not breathe. The air passes from the back of the nose into the windpipe, and so into the lungs. If we look at a butcher's shop we may see "the pluck" of a sheep hanging up on a hook. This pluck consists of the dark brown liver, the red oval-shaped heart, and the pale pink lungs, the "lights." They hang by a white ringed tube, the windpipe. The air passes down this tube, which is divided and subdivided into



THORAX.

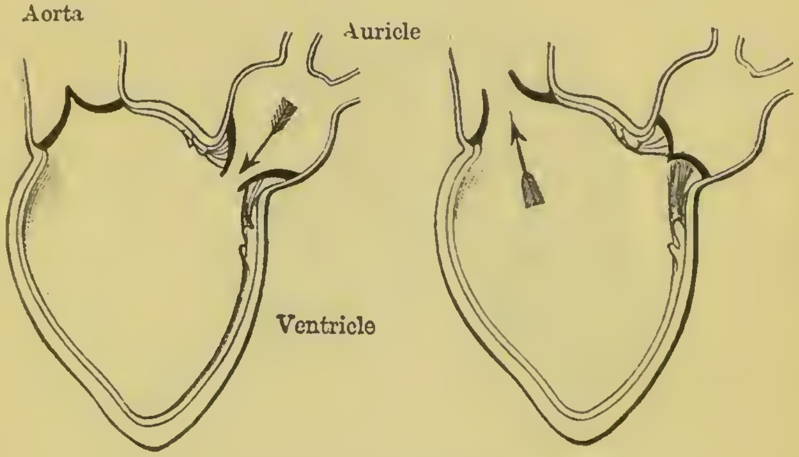
smaller and smaller tubes in the lungs. By these means the lungs are filled with air.



WINDPIPE AND AIR-TUBES—ONE SIDE COVERED BY LUNG.

The lungs are double, *i.e.* there is a right lung, and a left lung. The right lung is larger than the left. The chest holds the lungs, with which we breathe ; and the heart, which makes the blood circulate through the body. Across the bottom of the chest is stretched a muscular sheet which goes down each time we breathe "in," while the ribs are pulled upwards, and so the air is sucked into the thorax, or chest. When we breathe "out" it goes up; and when next we breathe "in" it goes down again. This is called the "midriff" by butchers, and the *diaphragm* properly. The latter is a Greek word meaning a partition, or fence.

The heart is a hollow muscle; when it draws in, or contracts, the chamber is lessened and the blood driven out of it; when it stretches out, or relaxes again the blood runs into it. Its movement is at regular intervals, or "rhythmic."



THE TWO HALVES OF THE HEART LAID OPEN.

In the pluck hanging up we may see white pipes springing from the red flesh of the heart. These are blood-vessels. The vessel going from the heart is called the *aorta.* The aorta is like the trunk of a tree; it divides into branches, the *arteries,* which are divided and subdivided into smaller and smaller branches, till every part of the body is full of little vessels containing blood.

These many little vessels then gather together into larger vessels called the *veins,* as rivulets unite to form a river; and by means of these the blood gets back to the heart.

The heart is double. When the blood from the veins reaches the heart, it goes into the right half of the heart. This right heart sends the blood into the lungs, where it comes into contact with the air we breathe. The blood so passes from the right half of the heart by a vessel called the *pulmonary artery,* or lung artery; which also is divided into lesser vessels, as the aorta is. The blood returns to the heart by veins which open into the left half of the heart. The left half of the heart then sends the blood over the whole of the body. The lung blood-vessels are called the "lesser" circulation; the other, going all over the body, except the lungs, is called the "greater" circulation. By these means the blood goes round and round

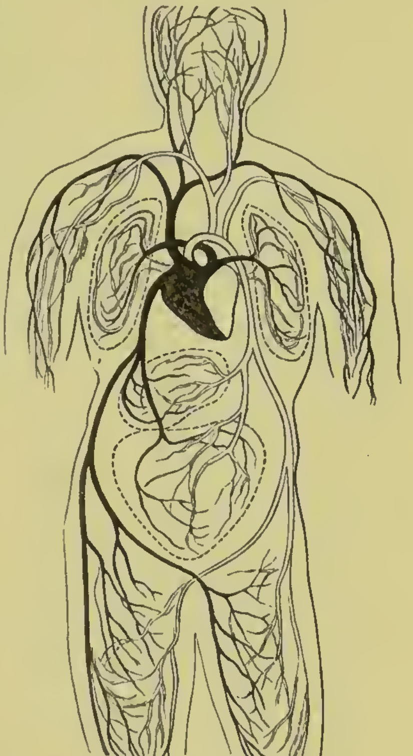


DIAGRAM OF THE CIRCULATION—(the veins dark).

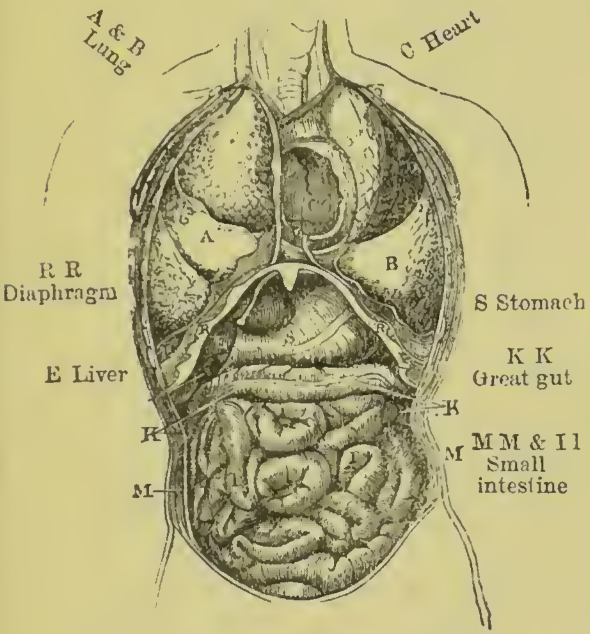
in the body, forming what is called the *circulation.*

To prevent the blood flowing backwards the heart contains *valves.* These open readily if pressed in one direction; but close if pressed in the other. There are also valves in the veins.

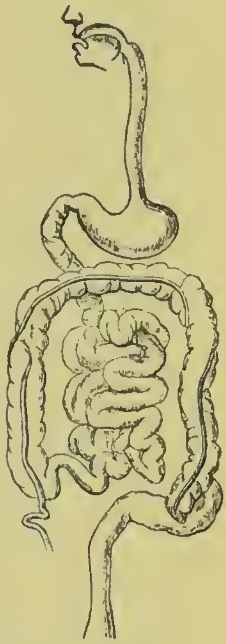
We cannot stop the heart's action if we wish to do so; nor yet can we give over breathing at will except for a moment or two; both are what are called "involuntary" actions, that is they do not depend upon the will.

The belly is also called the *abdomen.* It contains the stomach, the bowels or gut, and the liver. The gullet, which passes from the mouth through the chest, is a narrow tube which opens into the stomach. The stomach is a bag in which the food is digested; after the food is digested it passes along the bowels. The gullet is nine inches long; the small gut from the stomach is twenty feet long, and is coiled up in the abdomen. The last part of the bowel, the great gut, is five feet long; and is shaped like a horse-shoe with the toe of the shoe upmost, touching the midriff.

On the right side of the abdomen lies the liver, a large organ. The "fuel-food" of the body is stored up in the liver, from each meal; and on this store we exist and are kept warm between our meals. There is on the left side the *pancreas,* or sweetbread, which aids in digesting the food after it has left the stomach. The spleen, or milt, a bluish-red mass about as big as the heart, also lies on the left side. The spleen helps in making the blood. The kidneys lie close to the back, and



THORAX AND ABDOMEN LAID OPEN.



DIGESTIVE CANAL.

can be seen as two dark brown bodies in the midst of the white fat in the sheep, where the hind legs come off from the trunk. At the bottom of the abdomen lies the bladder.

The brain, the lungs and heart, and these different organs in the abdomen are called *viscera.* The backbone forms the back of the abdomen and is fixed; from it come flat muscles which form the soft front wall of the abdomen. A blow on this soft surface is very dangerous, and may easily kill the person struck, as there are no bones to protect the contents of the abdomen.

CHAPTER IV.

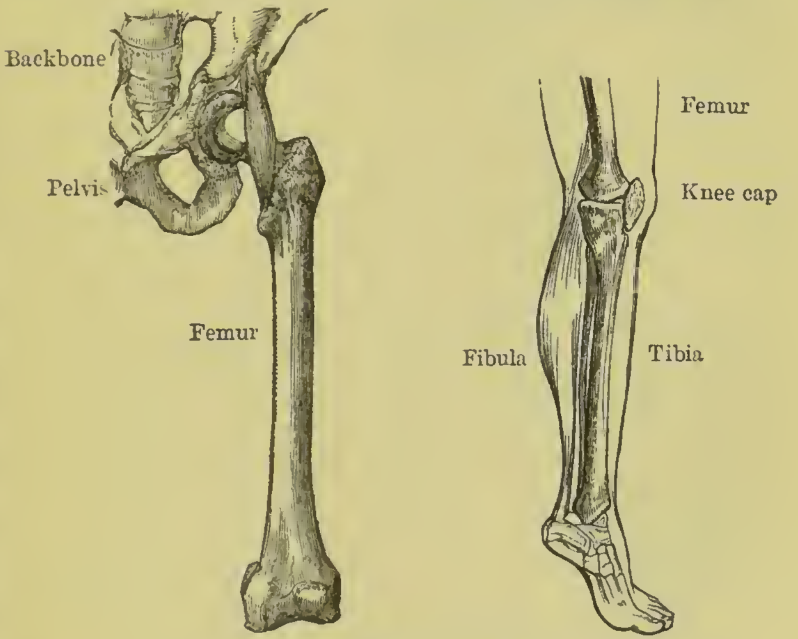
THE BUILD OF THE BODY—(*continued*).

NOW we come to the framework of the body, the bones and muscles (the red flesh).

By means of bones and muscles we move and run. They are the framework of the engine; while the chest and belly are the boiler and tender: our food being the coals. The brain is like the engine-driver who directs all. When the engine-driver moves a handle, the steam rushes into the machinery and puts it in motion. When we wish to move, a message goes from the brain to the muscles along the nerves; and the muscles move the bones.

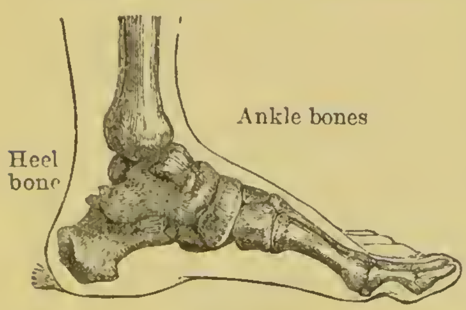
The bones are hard substances which do not bend. If we had no bones in our legs we could not stand. If bones had no joints we could not move. On the backbone you will remember there are two girdles of bones, the "shoulder girdle" and the "pelvic girdle." The pelvic girdle, or "pelvis," receives the backbone which is wedged into it; and from it come the two legs which are movable. On these legs we stand; and by moving these legs we run and walk.

The bones of the legs have heads, which fit into cups on the pelvic girdle ; and so the trunk is supported on the legs. These joints are called the hip-joints. To prevent these bones from slipping out of their cups, the bones and cups are tied together by strong white cords called *ligaments.* These ligaments are not stiff. The top bone of the leg is called the *femur,* or thigh-bone, and is the biggest bone in the body. It reaches down to the knee. At the knee-joint the thigh-bone meets the bones of the lower leg, to which it is fastened by strong ligaments. The knee is a simple hinge-joint by means of which we can kick the leg loosely backwards and forwards. In front of the



UPPER AND LOWER LEG BONES.

knee-joint, to protect it from injury, is the knee-cap, or *patella*.

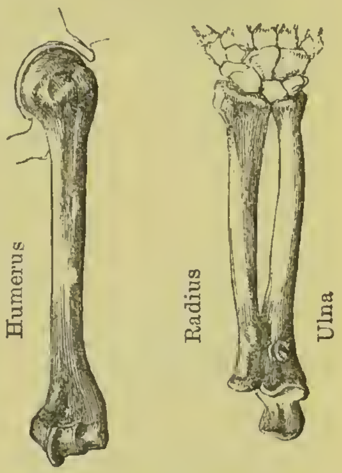


FOOT.

The bones of the lower leg are two—the main bone, or *tibia*, the splint bone, or *fibula*. It is because the bone is in two pieces that we can move the foot from side to side, or turn it round. These two bones are tied to the foot at the ankle-joint. The ankle-joint is made up of a number of small bones tied firmly together by ligaments, so as to be strong enough to carry the weight of the body. The bone which projects backwards is the heel-bone. The foot forms an arch known as the instep, with the heel at the back and the toes in front; on this arch the body rests. The foot is made up of small bones tied tightly together by ligaments in a lump, till we come to the toes. The toes are ten in number, five in each foot. By the toes we spring in walking. The foot, thus made up of many bones, bound together, is strong and yet can easily be moved. We can use the foot to kick with, as at foot-ball.

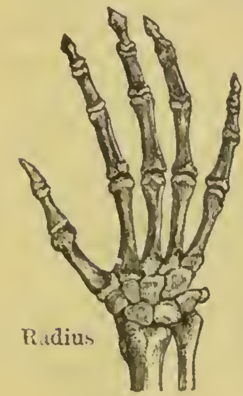
UNDER SURFACE OF FOOT.

From the "shoulder girdle" come the arms. The shoulder girdle consists of the collar-bone, or *clavicle*, and the shoulder-blades, or *scapulæ*. They are fastened to the trunk; the collar-bone at the top of the breast-bone, or *sternum*, and the shoulder-blades at the back. At the shoulder they form a cup which receives the main bone of the arm. The shoulder-joints are so made as to admit of great movement. The arm can be freely swung about in all directions. Then the main bone of the arm, or *humerus*, goes to the elbow, where it meets the two bones of the forearm. These two bones are called the *radius* and *ulna*. They are more nearly of a size than the two bones of the lower limbs. The elbow, like the knee, is a simple hinge-joint. But the wrist is a very movable joint, made up of very many bones tied well together. By such means the hand can be turned over, or *rotated*. From this wrist come the bones of the hands, which end in the thumb and fingers. By means of the thumb and fingers we grasp or take hold of things, as a stick; or when the fist is doubled, or closed on itself, we can strike a blow.

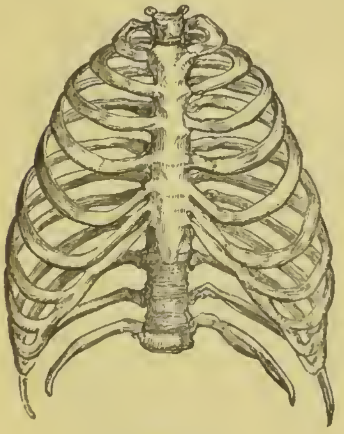


UPPER AND LOWER ARM BONES.

There are many little bones in the wrist united by ligaments. The bones of the hand, between the wrist-joint and the thumb and fingers, are called the *metacarpal* bones (*carpus* is the Latin word for the wrist). The metacarpal bone of the thumb stands off from the other four, which go to the fingers; and the thumb can meet or be opposed to any of the fingers when desired, like the two claws of the lobster; or the thumb and finger can be placed together, as in putting the hands into the pocket, or into a bag. This freedom of the thumb is most important to the usefulness of the hand in working. The ends of the fingers have on the outside, or back of them, nails; while the skin of the tips is very sensitive, and by means of them we feel. Thus we can tell whether a surface is rough or smooth, a substance hard or soft, hot or cold.*



HAND.


THORAX.

The shoulder girdle is fastened to the chest, or *thorax*. The thorax consists of the backbone of the back, from which spring the ribs, twelve in number. The front is formed by the breast-bone, or *sternum*. The ribs come around from the backbone and unite with the sternum. The top ribs are fixed; the lower ones bend and move in the act of breathing. In the lower animals, as the crocodile, there are ribs in the belly.

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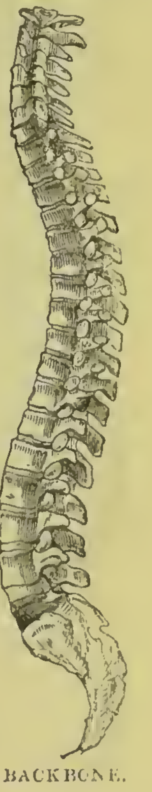
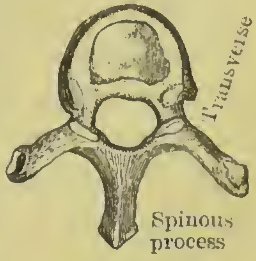
* Here the teacher should show the class how the thigh can be moved back and forward, or rotated. Also the movement of the knee, and the rotation of the foot. Still more the great movement of the shoulder, the elbow movement, and the rotation of the wrist, and the movements of the hands and the use of the thumb and fingers should be demonstrated.


BACKBONE.

The backbone consists of twenty-five pieces above the wedge-like bone, the *sacrum*, which is wedged into the pelvic girdle. The lowest pieces are the thickest and biggest. The *lumbar*, or loin vertebræ, are five in number. Above them are the twelve *dorsal*, or back vertebræ, from which spring the ribs. They are smaller and thinner. At the top are the seven *cervical*, or neck vertebræ. The whole forms a pillar or column, tapering as it goes up.

This column is solid in front, each segment being separated from the next one by a piece of gristle; and so, though solid, it can be bent. The hinder surface of the column is not solid but channeled, as now to be described. From each segment pass two processes, or projections of bone, which go backwards from each side. They unite at the back, and so a channel is formed, down which passes the spinal marrow. In this bony canal the



VERTEBRA.

marrow lies protected from injury. From this bony arch of each segment sticks out a piece of bone known as "the spinous process" of each vertebra; to these are fastened the muscles which keep the flexible spinal column erect, and lift the head and shoulders when the back is bent. On each side are processes (transverse) to which the ribs are attached.

At the top of the neck-vertebræ is the skull. This globe of bone is made up of several bones united together by seams, or *sutures,* so closely that it is not easy to separate them. There are also the bones of the face, the jaws, and the nose. The soft brain within the skull is thus safe from injury; but blows upon the head may kill by breaking through this hollow globe of bone, or even by the shock of the blow without breaking the skull. From each side of the skull project ears. Through the interior of the ear we hear.

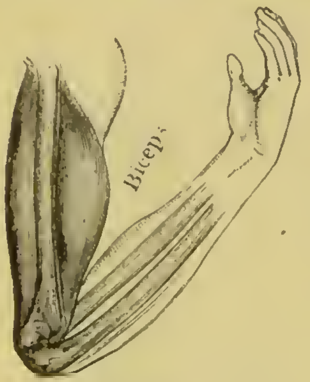
SKULL.

The muscles of the body clothe this bony skeleton; and move the bones of the limbs, turn the head, and bend the back. They are so placed on the bones that the latter must necessarily be moved when the muscles contract, or grow shorter. Each muscle consists of a bundle of little threads or fibres, which contract and relax, or grow long again, at will. In the heart this contraction and relaxation causes the blood to flow. In the leg the contraction of the muscles of the calf draws the heel off the ground when we step. If a child will put his left hand on his right forearm and grasp it firmly, he will feel this change in the muscles, as he closes his right hand, and opens it again.

Along the hands and feet run *tendons*, or cords attached to the muscles, by which the toes and fingers are moved. If a child move his left hand to the back of his right hand, and then open and shut the right hand, he will feel these tendons gliding under the skin at the back of the hand.

MUSCULAR FIBRE.

On these muscles depend what we call strength. Thus one boy is stronger than another because his muscles are stronger. By these muscles we can tell how heavy a thing is by trying to lift it. This is called the "muscular sense" of weight. The muscles consist of bundles of these minute fibres, which contract at will, and the contraction of the whole produces a shortening of the muscle: this moves the bones to which the muscle is attached. In the accompanying plate we see the muscle of the upper arm contracting, and so drawing the forearm up towards the shoulder. But if a boy is swinging from a bar, the hand being fixed, then,



BICEPS IN ACTION.

instead of the forearm being drawn to the shoulder, the shoulder is drawn to the forearm, and thus the body is raised or lifted up by the arm. So in the foot, the muscles which usually lift the leg and the body, can kick the foot out when a football is to be struck; and the force so expended sends the football a considerable distance. The upper plate (at p. 42) represents the foot at the time the kick is given. An archer pulls the string of his bow, and when he lets the arrow go, the elastic bow sends it far through the air. By means of the bow and its string the archer is enabled to make the contraction of the muscles of his arm propel the arrow. When the savage throws his spear, it is the contraction of the muscles which sends the spear along its course. A boy throws a stone by the rapid contraction of several of the muscles of the arm, from the shoulder downwards. The contraction of the muscles of both arms enables a boy to wield a cricket-bat so as to drive the ball far away. We wind up a watch, and, in doing so, coil up a spring inside. This in unwinding drives the wheels of the watch. The contraction of the muscles in the winding up is the force which makes the watch go. The spring can do nothing of itself. The force of the contracting muscles is but stored in the bow and in the watch-spring.

ANIMAL PHYSIOLOGY.

PART II.

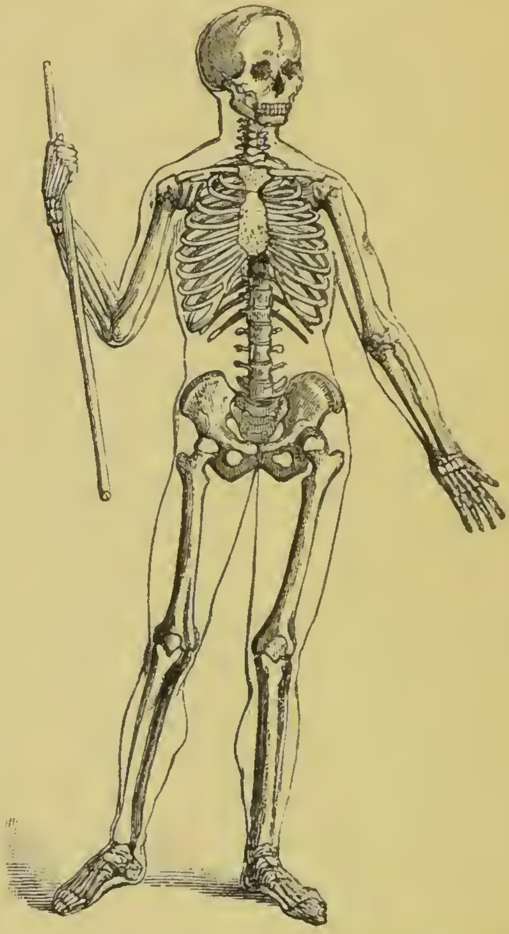
CHAPTER I.

MOVEMENTS OF THE BODY.

"The mechanism of the movements of the limbs and of the body as a whole," is a subject specially requiring *viva voce* explanation and illustration. No amount of written description can explain it: and the teacher must show to his class each movement before they can understand it.

MAN stands erect, and his backbone is vertical; while in animals the backbone proper is horizontal. By training, the monkey can be taught to stand erect on his hind-legs, but no monkey adopts this position in a state of nature; though the large apes nearly do so.

To enable man to stand erect there is a very large strong muscle which runs up his back. This muscle is called *the erector of the spine.* To the *pelvic girdle* are attached the big muscles which go down the thighs; and also the lower portion of this huge muscle which goes up the back. Having a broad base springing from the



back portion of the pelvic girdle, this large muscle tapers as it ascends, as does the spinal column itself. A piece of it is fastened to each vertebra, to that portion called the *spinous process* (see p. 34). Thus when the great muscle contracts, each segment of the spinal column is pulled upon. In the neck this muscle, *the erector of the spine*, becomes quite small, and the topmost fibres are fixed to the back of the skull. Now, when we stoop, the head and trunk are turned horizontally. This is done partly by the contraction of the muscles in the front of the body, partly by the relaxing or slackening of the "erector of the spine" allowing the body to fall forward to a certain extent. When the erect posture is regained, the whole of the muscles of the back of the body are put in action.

If we leaned forward too far we should topple over. So we fix the feet on the ground, the muscles of the calf keeping the legs fixed. Then the muscles of the thighs pull from above downwards and draw back the pelvic girdle ; the "erector of the spine" then pulls from the fixed pelvic girdle upon the spinal column, piece by piece, and upon the back of the head, and so the trunk is raised from a horizontal to an erect posture.

Now, I said if we "lean forward too far we would topple over." Why is this ? Do you know what *the centre of gravity* is ? Probably you do not. But you all have tried to balance a spoon on the edge of a teacup. You try, and try again ; and at last it balances. What have you done ? You have found its "centre of gravity," that is you have found the exact spot where you have an equal weight on each side. Move it ever so little either way, and down goes the heavier end. In other words, the centre of gravity is that point in any object through which the whole weight of the object seems to work. So long as that point is supported the object cannot fall.

Now the body has its "centre of gravity," and would topple over if the balance were lost. So if the body, when bent forward, got too far over the centre of gravity, it would topple over. In all our movements we must balance ourselves, or topple over. See a little girl carrying a baby in her arms ; her back is leaned backwards till, if her bonnet fell off behind, it would fall clear of her body. Then see a coalman with a sack of coals on his back: he stoops forward. In each case the posture is taken which will make the body, and the weight carried, balance. With the baby in front of her, the girl throws her body backwards; the coalman, with his weight behind his back, leans forward. The "centre of gravity" is important in walking and running. When we stand, a line from this centre runs down the middle of the arch of the foot. When we walk, the body is slightly inclined forwards; and when we run it is still more bent forward; because the centre of gravity is travelling from one foot to another.

Centre of Gravity.

Centre of Gravity.

Now, how do we walk? The trunk, and head, and shoulders, indeed all parts above the pelvic girdle are kept over a moving centre of gravity by the action of the lower limbs. If we walk slowly and carefully, we find that, as the foot which is moved is put out in front, the body is moved forward, so as to rest over the new centre of gravity. There is also the question of toppling over sideways; so the body is inclined a little sideways so as to bring it over the new centre of gravity. Sailors, when first they come on shore, roll sideways very much when they walk; they have not got their "land-legs," it is said. How is this? On board a ship, especially when rolling in the waves, the sailor has not only to find his new centre of gravity at each step, but he has a rolling surface to find it on. So he rolls about too. But in a day or two he recovers his "land-legs" and walks more like other persons, because he has firm ground, and not a rolling ship, on which to find his changing centre of gravity.

When we walk, the foot is lifted; the knee is raised by the muscles in front of the thigh, and of course it is raised in front of the body. Then the foot is thrust forward by the muscles in front of the leg, thigh muscles and leg muscles both, and it is allowed to fall on the ground. Then the trunk is moved over the new centre of gravity, and the weight will be felt passing from the arch of the foot on the ground towards the toes as the body is thrown forward. As the other foot reaches the ground the weight of the body is felt on the heel first, and then rests on the arch of the foot.

HEEL LIFTED.

As one foot is thrown forward, the muscles at the back of the leg of the foot on the ground are felt to contract. The knee is fixed by the thigh muscles, both back and front, and then the muscles of the calf lift the heel off the ground, and allow the weight of the body to rest on the toes; that is, they bring the centre of gravity forward. Then the weight of the body is thrown on to the foot in front, as it comes down on the ground; the weight of the body falling on the heel first, as before described. And so by advancing first one limb and then another, and by moving the body to the new centres of gravity, we walk.

WEIGHT ON HEEL.

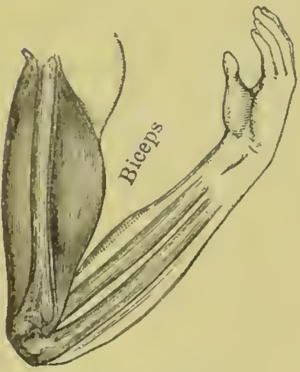
It was said above that a sailor does not easily get his "land-legs" when ashore; so a landsman has great difficulty in learning to walk steadily on the deck of a rolling ship. Though we all walk without conscious effort, this is only learnt after much toil, and failure, and trying again; as is seen in a child learning to walk. Slow, unsteady, it is at first; toppling over, forwards, backwards, or sideways. After a while it walks all right, but not with "the sure and certain step of man;" it easily trips. A little matter throws it off its centre of gravity, and it has not learnt how to readily balance itself; and so it falls to the ground. It takes two years for most children to learn to walk; and more for them to avoid being easily tripped up. Especially is a child liable to trip when running. In running the new centre of gravity is moving forward more rapidly than in walking, and the body is bent more forward; so if the child trips its toe against anything, it readily topples over on its face and front.

It takes a long time to learn to walk; and after this, though the child walks and runs, if it wish to skip it has to learn how to do it. How clumsy a boy is at first with a marble! He crooks his forefinger upon the top of his thumb, and places the marble in the hollow resting on the nail, and sends it out with uncertain aim. It takes some time for him to learn to place it firmly between the tip of the forefinger and the joint of the thumb, and then to shoot it out with precision. In time he learns to do this, and even to hit pretty often another marble at the distance of three feet.

All muscular movements are learnt with pains and trouble. When we write we hold the pen betwixt the fore and long finger and the thumb, and then move the pen up and down on the paper. At first it is impossible to make a straight stroke; this learnt, "pot hooks" follow; then letters, and then words. For long the writing is done slowly, painfully, with a sense of effort; but it becomes easier and easier by practice, until steady, regular handwriting is acquired. Nevertheless each child writes its own hand; just as it has its own voice. And this is because the muscular action of no two people is exactly alike.

Now let us see how another movement is made, viz. taking food to the mouth. A piece of bread is on the table which we wish to eat. First we must seize it. The arm is reached out by the action of the muscles of the upper arm, which thrust the forearm forward. The fingers are also thrown backwards, or in other words the hand is opened, by the action of the muscles at the back or outside of the forearm, the *extensor* muscles which extend the hand. The thumb is thrown outwards by a muscle which can be felt to move on the outside of the arm. When the hand is placed over the piece of bread, the fingers are drawn towards the palm by the muscles of the inside of the arm, the *flexors* or bending muscles. The thumb is bent inwards by the muscles of "the ball of the thumb." Thus the fingers and thumb are brought together, so that the piece of bread is grasped, or taken hold of.

Then there is the getting of the piece into the mouth. The muscle of the upper arm on the inner surface, the *biceps*—the muscle which is offered when a man or boy asks another to "feel his muscle"—is put in action, and the forearm is drawn up towards the mouth. While this is being done the hand is turned partially over, or *rotated*, so that the palm or surface of the hand is turned to the face and mouth. The morsel is seized by the two lips and drawn into the mouth within the teeth. Here it is taken by the tongue and thrust betwixt the molar teeth; there it is chewed. Each time when the teeth are separated the tongue gives the morsel a little push over; then down come the teeth upon it, as it seems; but really the movable lower jaw grinds it against the fixed upper jaw. After it is chewed



BICEPS IN ACTION.

THE BICEPS.

sufficiently, a swallowing movement is made which forces the mass into the funnel-shaped top of the gullet; when, by an involuntary movement of the gullet, it is swept into the stomach; this movement being due to a wave-like contraction of the annular or circular muscular fibres of the gullet, or œsophagus. The hand is removed from the mouth by the action of the muscles at the back or outside of the arm.*

Now let us see how we breathe. You have been told before that the chest is closed below by a muscular sheet, known as the *diaphragm.* When we breathe in, or "inspire," this descends, and the contents of the abdomen are thrust downwards, as can be felt by the hand placed over the stomach. Then, when we "expire," the diaphragm goes up again. It is arched on "expiration," arched upwards into the thorax. On "inspiration" it is pulled more flat, that is it descends; as it descends the lungs follow it, being filled by air coming down the windpipe.

But there are other movements in respiration. If you watch a woman sitting quietly, reading or sewing, you will note how the bosom heaves—that is, rises and falls. The front of the chest is pushed forward, and then falls back again. It is pushed forward at the time when the diaphragm descends; that is, the chest is made deeper from behind forwards, while the descent of the diaphragm makes it larger. Being an air-tight chamber, the chest, when so enlarged, is filled with air. The lungs expand on inspiration. On expiration the chest is lessened in size. The diaphragm goes upwards, while the bosom falls; that is the *sternum*, or breast bone, falls, and the chest is lessened from before backwards; and the air is expelled (partially only, as we shall see further on) from the chest.

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* The teacher should go through these different movements before the class.

Then there are other muscles which help when the breathing is difficult. These are the muscles of the neck, and of the chest and arm. If you note persons with difficulty of breathing, you will see them place their elbows on the table and lean on them. By so doing they fix the shoulders, and then the muscles from the chest to the shoulders can help in the act of breathing. The points where they are fastened to the shoulders being fixed, these muscles, in contracting, pull open the chest, and so help in the act of inspiration. The muscles of the neck are also seen in action in the person who pants for breath. Such, then, is the muscular mechanism of the act of breathing.

CHAPTER II.

DIGESTION.

SECTION I.—THE PROCESS.

IN previous lessons we learned that the body is not unlike a steam-engine. There is the machinery, and there are the coals in the one; in the other there are the structures of the body and the food we eat. For the repair of the wear and tear of the body we require "tissue food." During early life, when the body is growing larger, more of the tissue food is required than in adult life, when repair is alone requisite. When the body has been wasted by disease, as typhoid fever for instance, much tissue food is required to repair the waste, and restore the muscles to their proper size. Tissue food is found in what are called *albuminoid* bodies. They have this name because they contain a certain white substance termed *albumen* (from the Latin *albus*, white). The white of an egg is almost wholly made up of albumen. The fibrine (or muscular portions of animals), caseine (or the cheesy part in milk), and the legumes (pea-tribe of plants) are rich in albumen. Cereals, wheat, barley, oats, and maize also contain albuminoid bodies. The special feature of these albuminoids is that they contain the element, *nitrogen.* This element is in its usual form a gas, and makes up a very large part of the air around us.

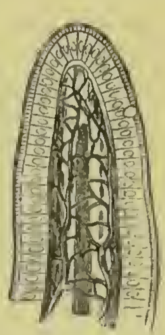
Now it should be remembered (p. 8) that combustion and oxidation are much the same thing; that is, both words express a process of combination with oxygen. It follows, therefore, that in nitrogen alone there could be no combustion; nitrogen would put out any fire. And not only so, but when nitrogen is in union with the other elements of our food, carbon and hydrogen, it prevents their ready union with oxygen; and so the tissues of the body do not themselves burn, or only to a small extent, while the "fuel food" is burnt in them. The tissues correspond to the framework of the engine, which is not burnt up along with the burning coals. Coals consist almost entirely of carbon and hydrogen gas, and by the union of these with oxygen we get heat produced. The heat of the body is due to the "fuel food" in it burning slowly with the oxygen of the air we breathe. "Fuel food" consists chiefly of carbon and hydrogen, and is found as starch, sugar, or honey; or as fat, oil, or butter.

To be stored up, either by vegetables or animals, all food must be in such a condition that it cannot be dissolved by water, else it would be liable to be washed away by rain. If a boy is too much afraid of going out in the rain, he is sometimes told that he is neither "sugar nor salt." But unless nature had provided that the food he takes into his tissues should be made insoluble by water, a heavy shower might leave little of him to come home again. Still, when taken into the stomach, and *digested,* food is made soluble. If food were not made soluble, and indeed actually dissolved in the act of digestion, it could not pass through the walls of the alimentary canal into the blood. So *digestion* is *solution* in fact. The starch we eat is converted into sugar in digestion.

But as sugar is soluble, it would drain out of the blood if it were not converted by the liver back into animal starch, called *glycogen.* By this means the body is nourished betwixt our meals. It would be inconvenient to have to be always eating; we could do little else. So the starchy and sugary materials of our food are stored up in the liver to feed our bodies when asleep or fasting. Starch is converted into sugar by the action of the *saliva,* or spittle. Fat is digested by the bile *secreted, i.e.* formed, drop by drop, in the liver, and also by the secretion of the *pancreas,* or sweetbread.

Albuminoid bodies are digested in the stomach by the action of the *gastric juice,* or secretion of the stomach. When dissolved they pass through the walls of the alimentary canal into the blood.

The following account is the history of our food after it is taken into the mouth. First it is chewed by the teeth, then it is rolled over by the tongue, then it is again chewed by the teeth; after this, it is rolled over once more by the tongue, and squeezed by the tongue against the roof of the mouth, and then swallowed. During this time it is well mixed with the saliva so that the starch is converted into sugar. In the stomach, which is a muscular bag, the food is rolled over and over and reduced to minute particles; so that it can all the more readily be dissolved by the action of the gastric juice. Two rings, one at the entrance and the other at the outlet of the stomach, keep the food in the stomach while it is being rolled over and digested. When the food is partially digested the ring at the outlet of the stomach relaxes a little, and the digested food passes out into the intestines. Here the fatty portions of the food meet with the bile which unites with the fat, and breaks it up into very small minute particles, so that it can be taken up from the bowels by tiny vessels called *villi* (the Latin for hairs). If an animal is killed when the digestive act is nearly complete, these "villi" are found crammed with minute specs of fat. Thus the body is nourished, while the undigested or waste matters pass out of the body by the bowels.

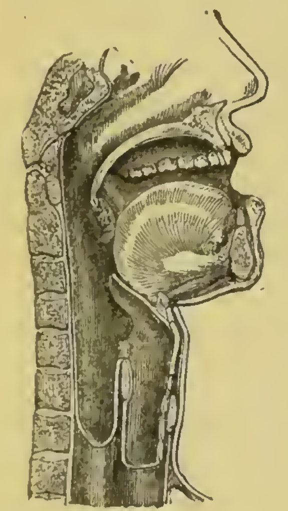


ONE OF THE VILLI (greatly magnified).

Such, then, is the "digestive act."

SECTION II.—THE ORGANS.

Let us now see what are the organs by which this "digestive act" is accomplished. The mouth has two lips, the upper and lower, by which the food is taken into the mouth. Then there are the teeth, thirty-two in number in the adult. The first teeth, or milk-teeth, are shed in childhood, and are no more than twenty in number. Then, as these milk-teeth pass away, the "permanent" teeth take their place. The teeth consist of lime, the outer part of them being very hard indeed. Some persons can even bite a piece out of a glass tumbler.



MOUTH AND THROAT.

The front teeth in each jaw are called the *incisor*, or "inbiting" teeth, by which we bite a piece out of an apple, or a cake; then come the *canine*, or "dog-teeth," on each side; after this the two *bicuspid*, or "two-cusped" teeth; and lastly the four *molar*, or "grinding" teeth. The tongue is muscular, and consists of the root, the body, and the tip. The saliva, or spittle, is secreted by three glands,[*] the largest of which are the *parotid* glands under the ear; "mumps" is an inflammation of these parotid glands. The *pharynx*, or top of the gullet, is funnel shaped, and down it the food passes to the stomach. The *gullet* is a muscular tube which contracts with a wave-like action from above downwards, and this commences with the act of "swallowing;" after which the act is "involuntary." At the end where the gullet, or *œsophagus* (food-carrier), enters the stomach is a little muscular ring which prevents the food from passing backwards up the gullet, when the stomach is rolling its contents over and over.

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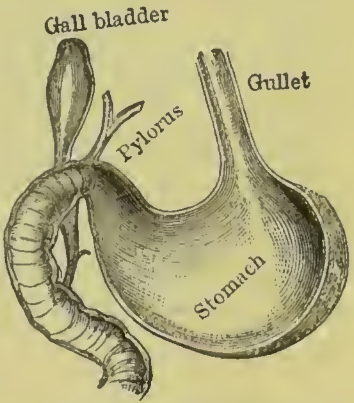
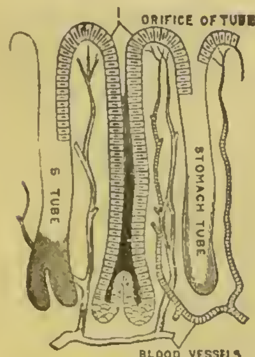
[*] A gland is an organ which has the power of forming a special liquid. It does this by selecting or separating out from the blood the necessary materials. To *secrete* means, in animal physiology, to select or separate out; and the liquid formed is a *secretion*.

The stomach is shaped like a "bag-pipe," and is a pouch or bag which, when full, is some twelve inches long, and four broad. It holds four or five pints ordinarily. It lies across the belly at its upper portion. The gullet end, or "cardiac" portion, points to the heart; the other end, called the "pyloric" end, points to the liver on the right side. The outgoing end carries on it a muscular ring, called the *pylorus*, or gate-keeper, which relaxes as digestion goes on, and allows the digested food to pass into the intestines.



THE STOMACH AND GALL BLADDER.

The stomach-wall consists of several layers: (1) the outer covering or *serous* layer; (2) the *muscular* layer, that which contracts, and rolls the food about in the act of digestion; and (3) the



INNER WALL OF STOMACH. *

mucous layer, from which is secreted the digestive fluid the *gastric juice.* This is secreted by these tubes seen in the accompanying wood-cut. The gastric juice is an acid fluid which will digest albumen, as pounded flesh, or white of egg, out of the body as well as in it. The *liver* is a large brown coloured mass lying chiefly on the right side. It is a very important organ—the "store-house" of the "fuel-food—and any derangement of it may poison the blood, affect the brain, and so disturb both body and mind. It is very soon affected by over-eating or excessive drinking. It secretes the *bile,* a fluid useful in the digestion of fat. On the left side lies the *pancreas,* or sweetbread. It secretes a powerful digestive fluid which completes the digestion of any starch which has not been converted into sugar by the saliva; it also carries on the digestion of albuminoid matters not perfectly digested in the stomach; and, along with the action of the bile salts, divides fatty matters into such minute particles that they can be taken up by the "villi" of the intestine.

The intestine also has an outer serous coat, a middle muscular coat, and a mucous lining. The muscular coat forces onwards the digested food, now called the *chyme.* As this chyme passes along the sugar, the digested albuminoids and the fat are taken up.

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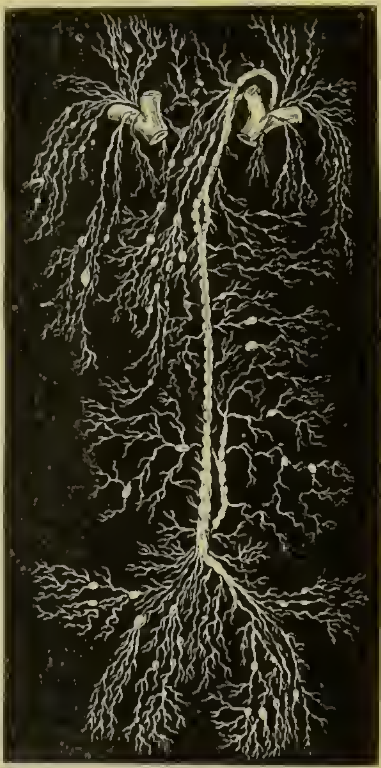
* Inner side above.

You will see in the cut, p. 51, one of the villi, or projections of the mucous lining of the intestine, full of vessels and tubes. These tubes in the villi are called *lacteals* (from the Latin *lac*, milk), and, contain a milky fluid. These lacteals pass through a number of glands in the belly, and then unite into one common duct (or leading pipe), called the *thoracic duct*, because it takes the fluid up into the chest and opens into a vein in the neck. It is about nineteen inches in length, and is as thick as a crow-quill. By this means nutritive material is furnished to the blood, partly by the thoracic duct, and partly by the animal starch in the liver.



LACTEALS ENDING IN THORACIC DUCT.

Such, then, are the organs of alimentation (or food-taking) by which the body is fed.

CHAPTER III.

THE CIRCULATION

TO *circulate* means to go round; and the *circulation* is so called because the blood goes round and round in the body. The nature of this circulation was first discovered by William Harvey, an English physician, in 1628. It is carried on by means of a number of tubes branching to all parts of the body. Those tubes, or vessels, in which the blood flows *away* from the heart, are called *arteries.* Those in which the blood flows *towards* the heart, are called *veins.* Joining these two sets of vessels there

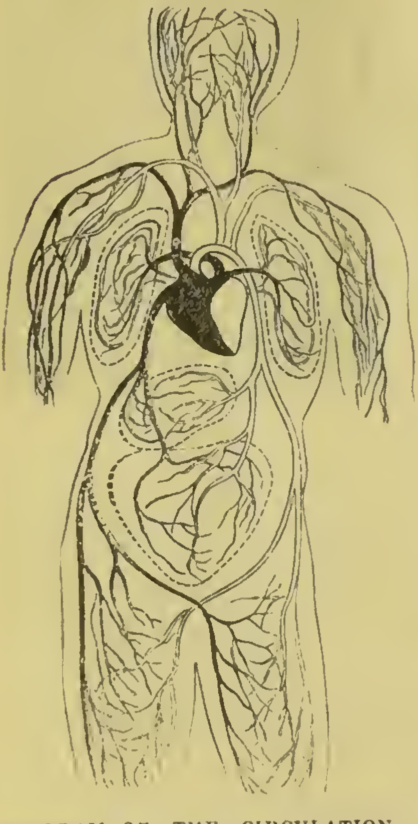
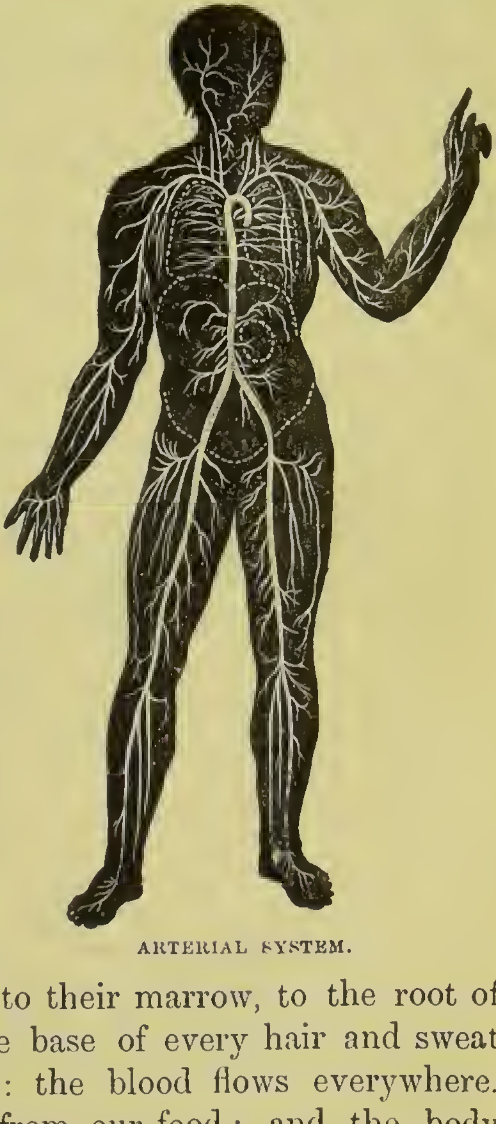


DIAGRAM OF THE CIRCULATION—
(the veins are dark).

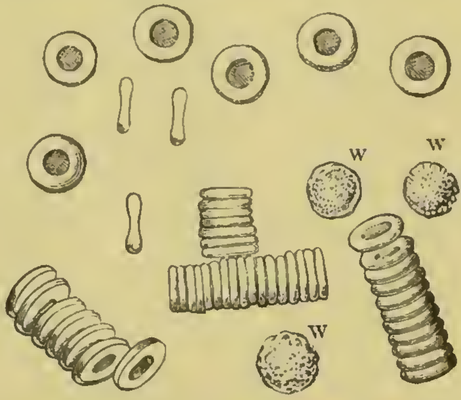
are the *capillaries*, or hair-tubes (from the Latin *capilla* a hair), so called because they are so small and fine. Going from the heart, with the rush of a torrent, the blood passes through arteries, growing less and less in size, till the capillaries are reached; its current becoming slower the further it gets from the heart. The beat of the heart is felt in the arteries and constitutes the *pulse*; which the doctor usually feels at the wrist.



ARTERIAL SYSTEM.

The tiny blood vessels called capillaries go everywhere; through and through the muscles, over and within the brain and spinal cord, through tiny holes in the bones to their marrow, to the root of every tooth, to the base of every hair and sweat gland in the skin: the blood flows everywhere. The blood is fed from our food; and the body is fed by the blood. If the blood is poor the body is weak. The blood not only feeds the body, but it is the means by which the waste matter of the body is removed and expelled from the body. If it were not for this circulating blood, the body would be poisoned by its own waste. The waste would accumulate, until the burden could no longer be borne, just as a fire may be smothered in its own ashes. The blood thus has a double use, and fulfils a twofold purpose.

Blood is a deep crimson fluid. The colour is due to little bodies in it called "corpuscles," (from the Latin *corpusculum*, a little body). Seen under the microscope the blood is crammed with these little bodies. Nearly all of them are red in colour, a few are white. The red corpuscles are shaped like discs (or round flat plates). These red corpuscles are the means by which the chemical changes are carried on in the body. In the lungs, in contact with the air we breathe, these red corpuscles give off carbonic acid gas and absorb



BLOOD CORPUSCLES—THREE WHITE.

oxygen gas. This change causes the blood to alter in colour. Venous blood is dark in hue; arterial blood is bright crimson. The oxygen changes the colour. These tiny corpuscles carry with them this oxygen gas to every part of the body, into the centre of the brain, and as far as the root of the great toe nail. By means of the oxygen carried by the red corpuscles the waste of the body is burnt, or oxidised, and thus removed.

But the nutrition, or feeding of the tissues of the body, is not carried on by these corpuscles, but by the fluid portion of the blood. Each tiny artery ending in capillaries carries to the tissues of the body blood rich in nutritive material; some of the serum (the fluid of the blood) feeds the tissue; the rest of the blood goes past into the veins, and so back to the heart; thence it flows on to the lungs to give up carbonic acid, and get some more oxygen; and afterwards back again to the tissues.

A very busy round these minute corpuscles have! Night and day, whether we are asleep or awake, these tiny carriers are as busy as bees. In ceaseless round circulates the blood; the heart beating with regular stroke, pumping the blood along. The tissues of the heart wear out, the blood brings new material for repair; and thus the body lives. The little corpuscles wear out; and new ones are supplied from the food we eat. The tissues take from the blood nutritive material; and the blood is fed from the food we eat. The blood feeds the body; while the oxygen it carries with it unites with our "fuel-food" to produce our body-heat, and removes waste matter from the tissues by oxidising the waste. The hot blood flows from the warm centres of the body to the cold extremities, and so keeps them warm also.

A very useful fluid the blood! And well might it be said, "the blood is the life." Without it no muscle could contract, no nerve carry a message; without it an injury to the skin could not be repaired, or a wound healed. It is the blood which keeps the body alive.

Now let us see how and by what means this vital blood is made to circulate. We will start from the heart; and come back to the heart when we have gone the round of the circulation. The warm red oxygen-laden blood comes from the lungs to the heart, by what are called the pulmonary veins (*pulmon*—a lung).* The heart, we have said before, consists of two halves—a right and a left heart. The blood from the lungs passes into the left heart. Each half of the heart is divided into two portions, (1) the *auricle*, the upper part, and (2) the *ventricle*, the lower part.

Between the "auricle" and the "ventricle" lie the valves on both sides. It is by means of these valves that the blood is made to flow forward, and cannot get backwards, when the ventricles contract. It is just the same as the valves

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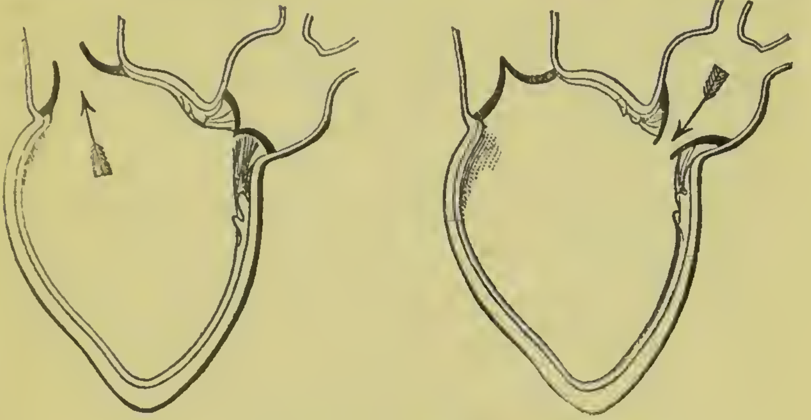
* Observe that these vessels *do not contain venous blood.* They contain fresh or arterial blood. Still they are called veins, not arteries, because the blood in them flows *towards* the heart, not *away from* it.

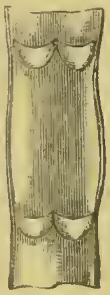


THE TWO HALVES OF THE HEART LAID OPEN.

of a pump. They allow the fluid to pass through them, but will not allow it to get back again through them. They open to let the blood through and close to prevent its return. They float back when the blood is rushing through them ; when the ventricle contracts, the valves are closed, *i.e.* their free edges are driven together closely ; there is no escape backwards for the blood, so it passes into the *aorta*, or great artery. The aorta is an elastic tube, one end of which is fastened to the left heart. Being elastic, it is stretched when the left ventricle contracts and forces the blood into it. Being elastic, it tends to shrink again and presses on the blood in it, which would go back into the heart if it were not prevented by valves placed at the bottom of the aorta, where it is fastened to the heart. Three little cusps, or pointed flaps, are there ; they float to the sides of the aorta as the blood rushes through; but when the elastic aorta rebounds, the blood gets behind them and their free edges are driven together close and tight; and so the blood cannot get backwards, but must go forward to the end of the aorta.

The aorta goes up from the heart and curves over to the backbone, and then runs down the front of the backbone, so as to be safe from injury. At the curve it gives off the arteries for the arms and head. Then it gives off little arteries, one to each rib, until it pierces the diaphragm; here it gives off a large artery which divides into three lesser arteries, one to the stomach, one to the liver, and one to the spleen. After this it gives off two arteries for the intestines, and a pair for the kidneys. Then it divides into two main arteries, one for each leg. Each of these main arteries subdivides again until, at last, each toe has an artery on each side of it. Betwixt the artery and the veins lie the capillaries; after passing the capillaries the blood comes into the "venules" (little veins), and then into larger veins, with a main vein for each leg. These main veins meet near where the aorta divides, and then form a main trunk-vein to the right

ARTERY, VEIN (dark), AND CAPILLARIES.



VALVES OF VEIN.

side of the heart. It is easy to see how the blood goes down the legs; but how does it get up again? Water will not run up hill! These veins have valves in them which allow the blood to run through them, but close to prevent it flowing backwards.

The arteries which go off from the curve of the aorta to the head and arms subdivide, as do the arteries to the leg. A main artery goes with the upper main bone of the limb. When the joint, knee or elbow, is reached, where there are two bones, then there are two arteries. The arteries divide at these joints. Up the side of each finger runs a little artery, and at the tips of the thumbs and fingers these little arteries from each side run into a *plexus* (or net) of blood-vessels. The finger-tips are very sensitive; we can feel very acutely with them. Just as they are full of nerves (as we shall see), so they are full of blood. If the finger-tip is pricked, not only is the pain sharp, but blood flows freely from the tiny hole. From the fingers the blood flows up return veins in the arms back to the heart, as in the leg veins.

The blood goes to the head by a trunk artery, which divides in the neck into two arteries—the inner and outer *carotid* arteries. If the throat is cut it is from these arteries that the bleeding comes which causes death. The inner carotid artery runs to the brain, piercing the base of the skull, and then subdivides within the skull. A branch of it goes to the eyeball; and the doctor looks into the eyeball and observes the blood-vessels in it when he wants to know the state of the blood-vessels in the brain. The outer carotid goes to the face. The face and its bones are very full of blood vessels, so that the face keeps warm even uncovered, in very cold regions, when the rest of the body has to be clad in furs. The rich supply of warm blood keeps the face from freezing when any other part would be frost-bitten if uncovered. "Frost-bite" of the tip of the nose and the tips of the ears is, however, not uncommon in cold climates. The blood comes back from the head by the *jugular* vein on each side. These veins, with the veins coming from the arms, unite into a main trunk. This main trunk-vein from the upper half of the body, meets the main trunk-vein from the lower half of the body, just outside the right heart. This venous blood flows from the right heart to the lungs.

When the blood flows into the right heart it reaches the auricle first, and then through the valve gets into the ventricle. At this point, as in the left heart, are placed the valves which allow the blood to flow through, but which close and prevent its flowing back again when the ventricle contracts. The valve betwixt the auricle and ventricle on the *left* side of the heart is called the "mitral" valve; the one on the *right* side is called the "tri-cuspid" valve. These valves are liable to disease, and then the circulation is defective; and the person so injured is not able to do much work. From the right ventricle comes the *pulmonary artery.** It has, like the aorta, three valves at its root, which is fastened to the heart; these prevent the blood flowing backwards after the right ventricle contracts, and so it is forced into the lungs. The pulmonary artery divides into innumerable little capillaries, and these gather together into the pulmonary veins which go to the left heart. Such, then, is the circulation.

But there are some points to be noticed further about the circulation. When a tiny artery brings a supply of nutrition to any part, it was said that some of the serum, or liquid part of the blood, went to the tissue, while the rest of the blood flowed past to the vein. But as more of this nutritive serum goes to the tissue than is required, the surplus, or spare amount, has to be arranged for. For this end there are another set of vessels provided called *lymphatics* (from *lymph,* a term used of material formed from the serum of the blood). By these vessels the spare nutrition is caught and brought back to the blood. If it were not for this provision the spare serum would either be wasted or stay in the tissue, causing disease in it. These lymphatics are connected with the glands of the body, and join the lacteals, which, as we saw before, pour their nutritive fluid into the veins of the neck by the "thoracic duct." Thus there is no waste of the nutritive matter in the body.

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* Observe that this vessel *does not contain fresh or arterial blood.* It carries venous blood to the lungs to be freshened by the air. But it is properly called an artery because the blood in it flows *away from* the heart, not *towards* it (p. 56).

In the abdomen there is what is termed the *portal circulation.* The arteries which go to the digestive organs—the stomach, liver, spleen, and intestines—are large. The blood in this "portal circulation" is enriched in digestion by the sugar and albuminoids of our food. The blood collects again into a main trunk-vein, the "portal vein," which goes to the liver. In the liver it subdivides so that the blood can leave in the liver the sugar, to be converted into animal starch (glycogen), and the nutritive albuminoid matters. These little veins then unite again in the liver into a trunk-vein, which joins the great main vein coming up from the legs and trunk.

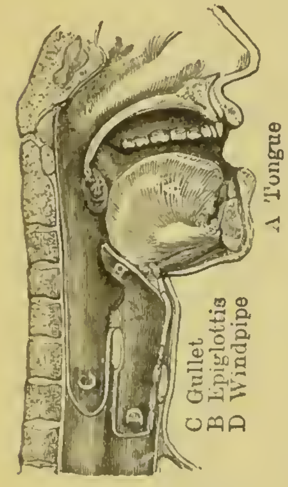
Thus we see that there are in the body three different circulations, all connected together: (1) the great, or *systemic* circulation, for the nutrition of the body tissues; (2) the *pulmonic,* or lesser circulation in the lungs, for the aerating of the blood; and (3) the *portal* circulation, for leaving the nutritive material of the body in the liver. Such, then, is the circulation with its admirable arrangements.

CHAPTER IV.

RESPIRATION.

IT was said in the last chapter that the blood is "aerated" in the lungs; *i.e.* it then comes into contact with the air we breathe. In the lungs the red corpuscles give off carbonic acid and take up oxygen gas. If we breathe upon a smooth surface, as the glass of a window, we soon see the glass become dim; and if we touch it we find it is wet. This is from the vapour of the breath—the water in the air breathed out of the chest. The body heat is produced, as you know, by the combustion, or oxidation of our "fuel-food." This food consists mainly of carbon and hydrogen. Oxidation produces carbonic acid (carbon and oxygen) and water (hydrogen and oxygen). In the lungs, then, oxygen is taken up, and carbonic acid and water given off.

There are many interesting points connected with the respiration. The air is drawn into the chest through the nostrils first. Inside the nose, or rather nostrils, are placed coils of bony plates, covered with very many blood-vessels. These are really "warming plates," like the plates of a stove. By this means the air is warmed before it goes into the chest. A blow on the nose causes the blood to flow freely, as naughty boys know when they come to blows. It is from the blood-vessels of these "warming plates" that the blood flows so readily when the nose is struck. Colds are caught in cold weather when the air is taken into the chest by the mouth instead of the nose. The air breathed by the mouth is cold, because there are none of these "warming plates" in the mouth; and so the air in the lungs is chilled. Babies are liable to colds in cold weather, because when they cry they breathe through their open mouths; and the cold air thus taken into the lungs sets up disease.



MOUTH AND THROAT.

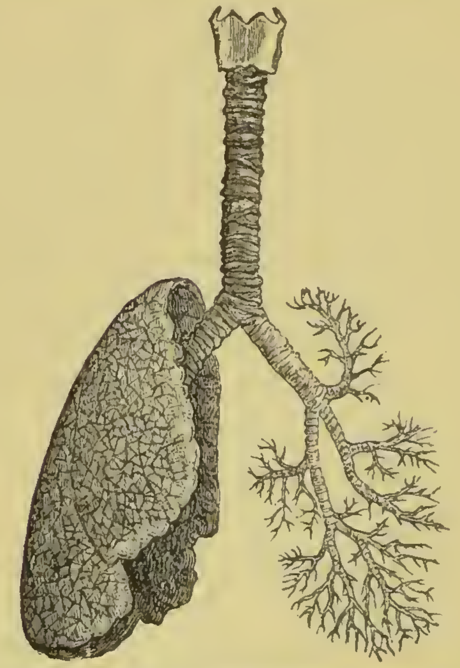
The air passes from the back nostrils into the windpipe. In doing so it crosses the gullet or œsophagus. Now comes a difficulty: if the air went into the stomach it would be wasted; if the food went into the lungs it would not only be wasted but it would cause much inconvenience. We all know when a crumb goes "the wrong way," how we cough until we get it up. In order, then, to prevent mistakes, the top of the windpipe is protected by a trap-door. A very clever fellow this little trap-door is. When anything is being swallowed, fluid or food, down goes the trap-door tightly, and keeps it out of the windpipe. This little watchful sentinel trap-door is called the *epiglottis*. It has no common name, as the butcher knows nothing about it. But it is a wonderfully useful little body nevertheless. If it were not for it our food would constantly be going "the wrong way."

If a child will grasp his own throat and "swallow" he will feel the top of the windpipe, known as the *larynx.* It is a sort of box in which is placed the mechanism by which we speak, of which we shall learn more further on. In this box are cords, the "vocal cords," which can be made tight or slack, and according to this is the tone of our voice. The air going back and forward to the lungs is made useful in this box (the larynx) for speech.

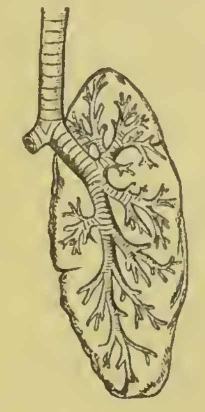
In the earlier lessons, we said if a child will look at "a pluck" hanging outside a butcher's door, he will see that it hangs from a ringed tube: this is the "windpipe." In man it is about 4½ inches long, and enters the top of the chest, or thorax. Then it divides into two, a branch for each lung. In the lung it divides and subdivides into first larger tubes, the *bronchi,* and lesser tubes, the *bronchiæ.* When from cold these air tubes become inflamed, we get *bronchitis,* a serious malady. Each little air tube ends in a *sac,* or pouch, not unlike a bunch of grapes.

This sac is surrounded by a membrane richly covered with a net work of blood-vessels. In these sacs the *aeration* of the blood, that is, its mixture with air, goes on; here it is that carbonic acid and water are given off, and oxygen taken into the blood.

We breathe about eighteen times a minute. When we breathe in, we are said to *inspire;* when we breathe out, we *expire*—according to the arrangements explained in Chap. I. pp. 46, 47. Do not suppose that all the air in the chest is expelled at



WINDPIPE AND BRONCHIÆ: ONE SIDE COVERED WITH LUNG.



TERMINAL SAC.

each expiration. A portion of air is always in the chest, and is called the *stationary air*. That which is taken in and given out each time we breathe is called the *tidal air*, because it flows in and out like the tide. The stationary air is steadily and perpetually taking up carbonic acid from the red blood corpuscles, and giving them oxygen instead, even when we are holding our breath, as well as when we are in the act of breathing.

The tidal air comes in to purify the stationary or *residual* air (from *residuum*, the Latin for a remainder) in the lungs. This residual, or stationary air in the lungs has been estimated to amount to 250 cubic inches; and the tidal air in each inspiration at 26 cubic inches. So we see that about one-tenth of the residual air is removed each time we breathe. The cool fresh air we breathe, though warmed in the nose by "warming plates" covered with hot blood, would be too cold for health if it were not for the large mass of air always in the lungs. The tidal air ventilates the residual air as a current through an open window ventilates a room.

The air which is inspired in the tidal air contains 21 parts of oxygen to 79 parts of nitrogen when taken in; but when expired there are only 16 parts of oxygen to 79 parts of nitrogen. The five parts of oxygen which have been taken up for the blood are replaced by five parts of carbonic acid given off from the blood. Thus the chemical changes required for the production of body heat by oxidation, and the removal of waste matter in the body, are carried on.

Much illness is the result of an imperfect supply of fresh air to our houses, and so of pure air to our lungs. If the respiration be stopped for a few minutes, probably about four, as in drowning, then death follows. But persons may be killed by an insufficiency of air; that is, they may get some air to breathe, but not enough to sustain life.

Every one has read the account of the "Black Hole of Calcutta." There Surajah Dowlah, a cruel tyrant, having captured a hundred and forty-six Englishmen, crammed them into a dark chamber where the little window did not admit of enough air for the poor wretches to breathe; and that, too, in a close hot Indian night in the month of June, 1756. They struggled and fought for air, and in the morning only twenty-three were alive. No less than a hundred and twenty-three of the poor things had died; not from being entirely without air as in drowning, but for want of a proper amount of it.

It is of great moment to see that we have not only fresh air, but "enough of it" for health. When persons do not get sufficient fresh air they do not grow into full-sized men and women. The labourer in the fields and the workers in cotton-mills sleep alike in small cottages; but the field labourer gets plenty of oxygen in the day and grows a big fellow; while the "mill-hand" is in a badly ventilated room, or mill, all day, and so never gets enough of oxygen; and the result is, he is often a stunted, pallid little man. So a deficiency of oxygen is one cause, at least, of the general inferiority of "big town" populations to country persons, in their size and weight.

When quiet, we breathe, as already said, about eighteen times every minute; but after a sharp run we breathe forty times a minute, or more. Now why is this? When the muscles of the body are put into action, the blood circulates more rapidly; and there is a greater production of body-heat, which is felt, as "getting warm." The blood goes more freely to the lungs, more oxygen is taken from the residual air, and more carbonic acid gas is given off. To keep the residual air fairly pure more tidal air has to be taken in; so we breathe more rapidly. When the body gets "warm," then comes *perspiration*, that is we sweat; and by the evaporation of this sweat the body is kept cooler than it otherwise would be.

Now how do we breathe? We do not breathe by will; certainly we can "hold our breath," or take a deep breath at will, but the breathing is carried on involuntarily. If this were not so the first sleep of Adam would have been death to him. In the brain, near the nape of the neck, lie the nerve centres which govern the respiration—the "breath centres." Messages run backwards and forwards from these centres by means of nerves to the respiratory muscles. When the blood is charged with carbonic acid gas these centres are irritated, and messages are sent off more rapidly to the respiratory (or breathing) muscles, to make them work faster. When the blood is fairly clear of carbonic acid, then the breathing becomes calm and quiet. After a sharp run it takes a few minutes for the breathing to become quiet.

When persons have disease in their lungs they breathe fast, even when quiet, and are "out of breath" on very little exertion. It is easy to see why this is so. They have not a proper "air-space" in their lungs. They have not room for 250 cubic inches of residual air, and so to keep this residual air fairly pure, the "breath centre" sends off messages to the muscles to work faster than the usual 18 times per minute. When such persons exert themselves, they are soon "out of breath." The same is the case in heart disease —when there is too much blood in the chest. In such a case the air space is diminished because the heart cannot send the blood fast enough through the lungs. Thus the blood accumulates in the lungs, and then the person breathes quickly, and pants for breath if compelled to move about.

Persons with disease of the chest should not live in close rooms if they can help it. For as the residual air in their lungs is reduced in bulk, cold tidal air breathed rapidly is apt to chill the residual air too much, and so they easily get "cold" in their chest. But they ought to have enough of fresh air to keep their residual air fairly pure, else the body at large must suffer from a want of oxygen.

ANIMAL PHYSIOLOGY.

PART III.

CHAPTER I.

THE NERVOUS SYSTEM.

MEANING OF THE TERM.

IN previous lessons on animal physiology we have learned the general build of the human body, and the uses of the muscles and the bones. We have seen that muscles are attached to the bones, so as to move the limbs when required. But how is it that the muscles are made to contract just at the right time? We have seen that in order to take a piece of bread from the table the arm must be stretched out, and that this is done by the *extensor* muscles. But how is it that the desire is followed by the action ?

There is first the thought, "I will take that piece of bread." Then there is the action ; the extensor muscles stretch out the arm. What is the connection between these two things ? It seems that a message must go from the thinking part to the moving part.

Children may naturally exclaim, "A message from my head to my arm! how can that be needed? I just want to move my arm, and it moves; that is all." No; it is not all! Sometimes if you lie on your arm it "goes to sleep," and then you can scarcely move it at all; at least, you cannot guide your fingers properly. You may want to take hold of a pen, for instance, but you cannot do it. Why? The muscles are there just the same. But for some reason or other the message from your thinking part—your head—does not reach them as usual.

When a "sensory" nerve is cut, then loss of sensation follows; when a "motor" nerve is cut, then paralysis of its associated muscle or muscles is lost.

"Divide the nerve going to a muscle, and the will in vain issues its edicts to that muscle; it cannot leap that narrow gap made in the continuity of the nerve."

We began with thinking of a railway engine; let us think of it again. Here is one standing at a station with steam up, and all the passengers anxious to get on; yet it does not start. How is this? There is something in the way, though it is a mile distant, and we cannot see it. Suddenly a bell is heard, a signal falls, and the engine is off. What has happened? Along one of the wires at the side of the railway a message has come, which says, "Line clear." That is what the engineman was waiting for. The moment he gets it he turns on the steam, and the train moves off.

Now, just as messages are sent along telegraph wires by the side of the railway to enginemen, at various places ; so messages are sent from our heads along little white cords called *nerves*, to every muscle in our bodies.

But this is not the only use of nerves. Besides carrying messages *from* the brain, they also bring messages *to* it. It is not the eyes that see ; it is the brain. A great nerve behind each eye carries up the impression made on the eye to a special part of the brain. Just so it is the brain that hears, and feels, and tastes, and smells.

From every part of the body, then, nerves run to tell the brain what is going on there. And equally by means of nerves the brain sends word out again what is to be done. This in general is what is meant when we speak of the *nervous system.* But we must now consider it more particularly.

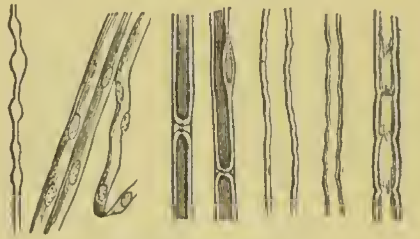
The nervous system consists, in man, of *the brain, the spinal cord,* and *the nerves.* From the brain pass nerves which set the muscles in action ; these are called *motor* nerves. Then we have a general sense of touch in the skin, and nerves of the special senses, sight, hearing, smell, and taste : these carry messages to the brain, and are called *sensory* nerves. There are also nerves going to the viscera, governing their action ; and to the blood-vessels ; but of these we need not speak further.

CHAPTER II.

NERVES AND NERVE CURRENTS.

A NERVE is a white cord when seen by the naked eye; and under the microscope this white cord is seen to consist of minute white fibrils.*

These fibrils, both in the case of "motor" and "sensory" nerves, can be traced from the brain to their very end. If the nerve be cut through, communication with the brain is interrupted. If the nerve in the upper arm be severed, the fore-arm and hand are *paralyzed, i.e.* sensation and power of movement are lost.



NERVE FIBRILS.

Now we know that a current passes along these nerve fibrils, just as a current of electricity passes along telegraph wires. We know further that an electric current will pass along nerves. If the electric current be applied to a motor nerve, its muscles will be excited into forcible action. If applied to the nerve of taste, it passes up to the brain and a saline taste is felt in the mouth; *i.e.* the impression made upon the sensory portion of the brain is the same as that of a saline substance in the mouth.

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* Fibrils—little fibres.

Still the nerve current is *not* electricity. The rate at which a "motor" nerve current passes along is 100 to 120 feet per second; while in a sensory nerve it is from 110 to 120 feet per second. Electricity, on the other hand, passes along at the rate of thousands of miles per second. Thus there is a perceptible time, though very short, betwixt seeing a blow coming and throwing up the arm to avert it. The impression travels from the eye to the sensory portion of the brain; from the sensory portion of the brain to the part which sends out impulses of movement (see further on); and from thence a motor current passes to the arm, which accordingly is raised.

Now this current does not pass along one nerve fibril all the way. Then how does it go? Nerve fibrils pass into "nerve ganglia" (*ganglion*, Greek for "a knot").

Think how a train on the Midland Railway starts from St. Pancras for Derby, with various carriages for different places. When it gets to Derby it drops the Manchester and Liverpool carriages, and takes up carriages from Bristol and

Nottingham, and goes on again for Sheffield. At these "junctions" lines come in, and lines go out again.

NERVE GANGLIA.

So it is with these nerve ganglia; nerve fibres come into them, and others go out. Impressions may run in and pass out to the brain; just as a passenger from Leeds to London comes in through Derby.

LARGE GANGLION.

But another passenger from Leeds may wish to go to Buxton, so he turns off at Derby. He does not go to London first, and then back to Derby, and on to Buxton. So a nerve impression may not travel up to the brain, but be "reflected" at one of the ganglia, or junctions, on the way.

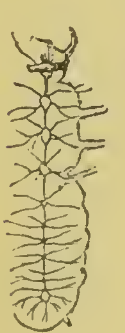
A crumb of bread gets into the windpipe, and a cough is set up to eject it. We cannot control that cough much ; it goes on without the "will," and is called a *reflex action.* The impression made by the crumb passes to the upper portion of the spinal cord, and is reflected back to produce the muscular movements which constitute the cough.

Many actions are of this "reflex" character, and do not require the brain for their performance. Thus if the brain of a frog be removed, and its foot is pinched, the animal will leap away from the irritation. If a drop of an irritant acid be applied to the thigh of a headless frog, the foot of the same side will wipe it away ; if this foot be cut off, after a while the other foot tries to wipe it away. So we see that, where a "sensation" leads to "motion," even distinct actions, involving a definite purpose, are reflex in character ; and can be performed without a brain. But for voluntary motion a brain is requisite.

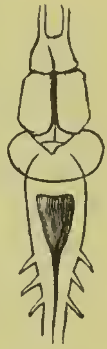
CHAPTER III.

THE BRAIN AND NERVES OF THE HEAD.

IN the lowest forms of animals there exists no separate nervous system. The tissue is muscular, but seems to feel as well as to move. A little higher in the scale of life there is a distinct mass to be seen,—the commencement of the brain. After this there develops a little mass of nerve-cells for the thorax, and another for the abdomen; each smaller than the primitive brain. Then in animals built in segments (the *Articulata*), there is a distinct nerve centre for each segment. An arrangement on much the same plan as the human nervous system is seen in this illustration of the nervous system of an ant.

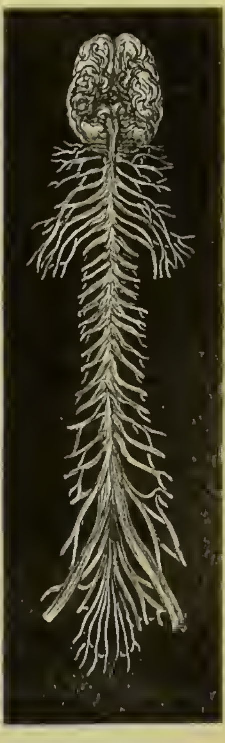


Here we see in the head of the animal a definite brain, with the nerves passing thence to the limbs. There is also a distinct bundle of nerve fibres passing down the body of the animal; this is the commencement of the spinal cord. In fishes there is a still more definite brain. The accompanying cut shows us a distinct brain and spinal cord in the frog, with nerves springing from each. In the human being we find the brain a very large mass in comparison with the rest of the nervous system.



Below we see the *cerebrum* and the *cerebellum*, *i.e.* the "brain" proper and the little "brain;" also the spinal cord, with nerves attached.

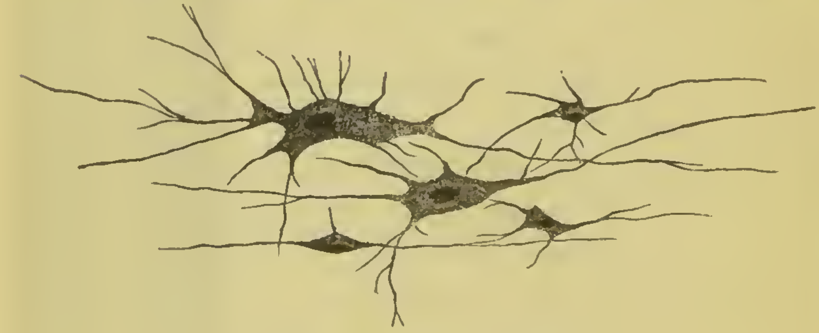
The brain proper consists of several parts, but we will not enumerate them till the *hemispheres* have been described.



The brain consists of two halves, of which the left half is the more important. We are, as a rule, "left-brained," as we are "right-handed." The motor fibres cross over in the base of the brain—why we do not know—so the right hand is ruled by the left brain. The left brain is the more active because its arteries are almost in a straight line with the heart, and so the blood goes to it more freely than it does to the right brain; and thus it becomes the more active hemisphere. As the left brain is the bigger, so the right hand is the one mostly used.

Now the brain is a very interesting organ. You see its surface is in *convolutions*, or folds. Its interior is white, while its surface is grey. It is this grey surface matter, the *cortex* (Latin for "bark"), which is the active portion. It is spread over the inner white portion. The white portion consists of nerve fibres running to and from the grey cortex, by which the grey portion is in communication with the skin and other sensory portions of the body; and with the motor apparatus, the muscles.

This grey cortex is very richly supplied with blood, and when the brain is active the blood-vessels are dilated, or widened, and the blood current rushes along swiftly. In sleep the blood-vessels contract, the blood current is slow, and the brain is "anæmic," or bloodless. The brain activity depends upon "cells" such as are here delineated. Now we



CELLS FROM HUMAN CORTEX.

have every reason to believe that in these cells the material records of our "recollections" are stored. In some way or other the memory of a blow, or a pleasant experience, makes its record on these "brain cells." You see they have tails, and it is by means of these tails, or "processes," that the stored recollections can communicate between cell and cell.

Thus we understand how what we call "a train of thought" is rendered possible. The idea passes along from one cell to another, calling out a part of the experience stored in each as it passes through that cell. This is rendered the more probable because in babyhood these cells have few or no "tails;" but they develop as the child gains "experience." In the brain of a man of active mind the brain cells have many tails. The larger cells are found without tails at first, but tails are soon developed. The large cells probably contain inherited tendencies; the small cells grow as the individual grows.

In old age the tails wear out, and along with this the memory fails. An old person says, "I can't remember; I have it in my mind, but I can't remember it." Often he will say, "Perhaps it will come to me after a while." In a little time he does remember. Here we have every reason to suppose that the cell in which this remembrance is stored has lost the tails most in use; and that it can only be reached by a roundabout hunt through little-used tails that are still unworn out. I do not say that this is as yet proven, but it is very probable.

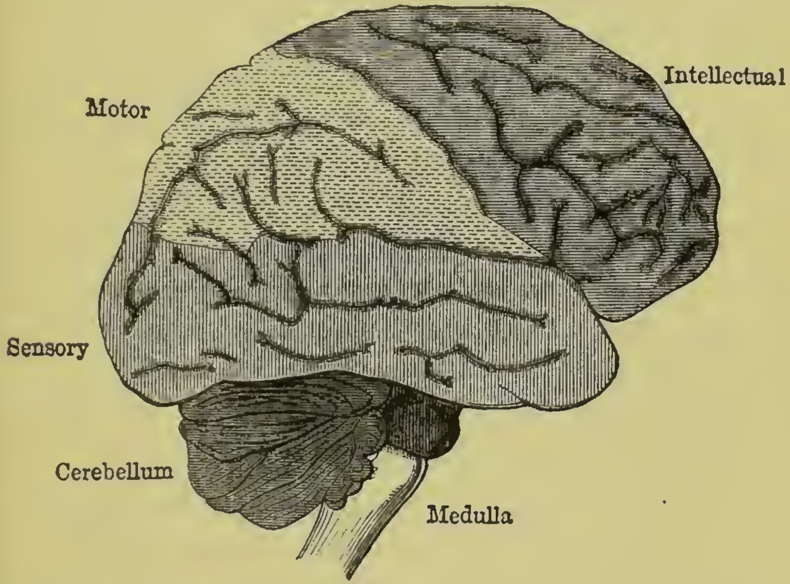
I have told you that in the brain of a young child there are "brain cells" without tails. I have also mentioned it as very probable that inherited instincts (that is, feelings and desires handed down from past generations) are locked up in these cells. Thus the young swallow comes back to the nest it was reared in. Across the continent of Europe, away over the Mediterranean Sea, the swallow comes back from the African desert to its home in England—to the particular nest under certain eaves. The young salmon goes down to the sea, but it does not lose itself: it comes back to its own river, back again to its own streamlet, to lay its eggs where its salmon ancestors have laid theirs before. Further, young salmon artificially hatched dread a net when put into their tank. These tiny little salmon-fry somehow recognise and dread a net, while they are indifferent to any other thing put in—such as a stick, for instance. They never saw a net, but there is an inherited instinct in them which is believed to exist in these "brain cells."

Now it was said that the grey matter is spread over the white inner portion of the brain. It is like a handkerchief crumpled up; so that if stretched out, the grey cortex of the brain would cover a large surface. In the lower vertebrate animals the surface of the brain is smooth. As they rise in intelligence, convolutions appear. These convolutions are more numerous in the brain of a clever man than in that of an idiot. The intelligence and the development of convolutions

BRAIN OF RAT.

go together. The more the convolutions, the greater the area of this grey cortex; the larger the area of grey matter, the greater the intelligence.

The cerebrum is divided into three portions or areas. In the accompanying engraving of the brain these three divisions are well marked. There is the *sensory* portion, lying underneath and to the back. To and from this run the sensory nerves. Then there is the *intellectual* portion of the brain in front. This is more especially the part used in thinking. Over the top, at about from ear to ear, lies the *motor* area, known as "*the motor band.*" This is the part that governs the motor nerves, and through them the muscles. You see a line marking off the thinking from the motor area.



This is called the *fissure of Rolando,* and is a deep gap in the brain. Then you see another line running betwixt the motor-band and the sensory area; this is known as *the fissure of Sylvius.*

In front of these fissures the sensory area is in contact with the thinking area. The front portion of the sensory area is the seat of the centres for the special senses—sight, hearing, taste, and smell. The hinder portion is the seat of the centres for general sensation, both of the skin and the internal organs.

The hinder part of the brain has a different blood supply from the rest of the brain, so that a very different condition may exist in the various portions of the brain. The hinder part of the sensory area may be badly supplied with blood, so that the person feels very ill and miserable; and yet the front portion of the brain may be working actively and be full of blood. Of course, when all portions of the brain are well supplied with blood, the person feels well and equal to work.

When a child is growing rapidly, the blood is drawn away from the brain to the bones and muscles; so that in "a growing fit,"—that is, a period of active growth—a child is languid, and cannot do its lessons well, because its brain is badly supplied with blood. When the "growing fit" is over, the blood returns to the brain; and when plenty of blood once more circulates in the brain, the child feels lively, and delights in its lessons.

Underneath the hinder portion of the brain is placed the *cerebellum,* or little brain. Now we do not quite know the function of the cerebellum, but we believe that it possesses a certain distinct power of its own. When we stand on an eminence overlooking a fine view, we enjoy the view without being conscious of any effort to keep ourselves in the erect posture ; it is maintained without conscious effort. Now it is probably the cerebellum which maintains this posture, while our brain proper is given up to the enjoyment of the view.

There are some other centres at the base of the brain, the most important of which is the *medulla.* This is the most vital portion of the brain, and injury to it is immediately fatal. It is placed at the junction of the brain and cerebellum with the spinal cord, and is at the nape of the neck.

In this medulla the centres which govern the muscles of respiration are located, as also the centres which regulate the circulation of the blood. (Certain it is that the rhythmic action of the heart depends upon little nerve-centres in the heart itself ; but these are controlled by centres in the medulla.) Consequently injuries, as blows, to the medulla are instantaneously fatal. In Burmah and some other countries criminals are executed by blows on the nape of the neck, which produce instant and painless death, because this is the seat of the medulla. This vital part is affected by narcotic poisons, such as opium and chloral. Here also apoplexy—the forming of a blood-clot in the brain—produces its fatal result.

In poisoning by opium or chloral, mere unconsciousness is of little or no moment in itself. The effect upon the hemispheres of the cerebrum is without danger to life. But when the poison is sufficient to stop the action of the centres for the respiration and the circulation, then life is gravely threatened. So in apoplexy; the blood wells out into the brain, and as it forms a large clot presses upon the hemispheres. Sensation and motion are abolished by pressure on the sensory and motor areas of the hemispheres, and so the person is unconscious and motionless. But there is no actual peril to life in this, and the person may still survive in a mutilated condition. But when the pressure of the effused blood reaches the medulla, the respiration and circulation are interfered with, and death swiftly ensues.

Now when "convulsions" occur, or, as it is said, a person or child has a "fit," the cells of the motor area discharge motor messages independently of the will; and the movements so set up are the "convulsions," or fit.

Such, then, are the contents of the skull, their position, and their function.

From the anterior and under surface of the sensory area and the lower portion of the brain spring a number of nerves. A pair go to the eyes, for sight; while a number of pairs go to the muscles of the eyeball, by which the eye can be moved, and vision directed to different objects without the head being moved. A pair of nerves go to the nose for smell; and half of one nerve goes to the ear for the purposes of hearing, the other half governing the features and the muscles of expression. Another nerve forms the sensory nerve of the face, and gives off branches to the lachrymal (tear) glands.

When we are in deep trouble, tears flow for our relief. The lachrymal glands (*lachryma*, Latin for a "tear") secrete a fluid when their branches are irritated, which wells out of the eyes as tears. These glands are readily excited when the emotions are disturbed in children; so to cry is regarded as childish. To restrain the tendency to cry is one of the characteristics of adult life; and of course to cry at little matters is essentially childish. But many a woman who struggles hard in times of trouble not to "give way" to tears, would be all the better for a "good cry."

Then there are nerves which go to the tongue for taste; and when bitter substances are placed on the tongue, then a flow of saliva follows, from the impression upon the sensory nerves of taste being conveyed to the secretory nerves of the glands of the mouth. In response to this impression the glands secrete the fluid known as saliva, or in common parlance "the mouth waters." When we are hungry, the smell of a good dinner will make the mouth water.

CHAPTER IV.

THE BRAIN AS THE ORGAN OF MIND.

THE brain is not the mind. It is, however, its organ; and we will now consider the brain briefly as "the organ of mind." The first thing the nerves do for us, as thinking beings, is to give us sensations. Then comes "consciousness" of sensations directing motion. The feeling of pain or pleasure prompts to some action. A sensation of pain in a young child causes it to cry aloud and to shed tears: that is, consciousness is linked with the emotions at first.

Then comes the growth and development of the "will," implanted on the emotions. A recollection of previous sensations causes "emotion." Thus a sick child when he sees a glass of disagreeable medicine, from the remembrance of its bad taste at a previous time, turns away in disgust to avoid the unpleasant sensation. He thus lets emotion rule him. But in consequence of this emotional act he is punished by the pain he suffers for want of the medicine; and the remembrance of this, after a little time, enables him to control the emotional impulse to refuse it. The remembrance of one sensation controls the emotion caused by the remembrance of another sensation, and so comes the will, *i.e.* the power to choose which of two or more things shall occur.

All our knowledge thus comes from sensation: either experienced by ourselves, or taught us by others. Thus, of painful bodily sensations we generally learn for ourselves; but of painful mental sensations the child is mostly taught by precept—the consequences are often too remote for it to see them. Thus a child is taught not to steal because it is wrong; and he believes this, and from principle does not steal. But a bad child steals an apple, or some other attractive object. No one sees him steal; and when the theft is discovered and the child is asked if he took the object, he probably tells a lie and says "No." He has not had strength to resist the temptation to steal; so when the impulse to tell a lie springs up, he tries to conceal his sin by falsehood. But he is found out and punished; and when the opportunity to steal comes again, the remembrance of the punishment helps him to restrain the impulse to steal: and thus one of the good effects of punishment is experienced.

This power to restrain an impulse is called "control." The power to exercise this "control" is otherwise called the "will." One child wills to steal; while another wills not to steal. Punishment helps the child to resist the impulse to steal by the remembrance of it; and so aids the development of the will. Now when a child is tempted to steal, if neither a very good child nor a very bad child, he thinks about the matter, and calculates or balances the risk of discovery and the pain of the punishment; that is, he "reasons."

Now this power of control is a great matter in conduct. Some cats and dogs will steal, no matter how much they have been punished; they cannot restrain their impulses. So it is with what we call the criminal classes—they cannot resist the temptation to steal; while other animals and human beings can successfully resist the temptation to steal.

The power to act rightly in moments of temptation is furnished by what is known as the "conscience." This is the higher portion of the mind, which controls or restrains the emotions underneath its sway. The education of the higher powers, and of the higher nerve-centres through which they act, is the best result of school work.

The child is first taught to sit still; *i.e.* to restrain the impulse to move about, so strong in all young animals. This educated self-control leads up to the highest qualities of mankind. An older child learns to stay in voluntarily to study its lessons, even when it is fine weather, and there is play out of doors. In adult life this educated control leads to many an act of self-sacrifice to aid another or to achieve some noble end.

Much of our "goodness" or "badness" depends upon inherited traits; that is, we resemble in character, as in person, our ancestors. It is much easier for a child of good parents and proper training to be good, than it is for a neglected child to be good. A great deal more patience and more pains are requisite to teach a neglected child to restrain its impulses, than are required in the case of a child more happily trained.

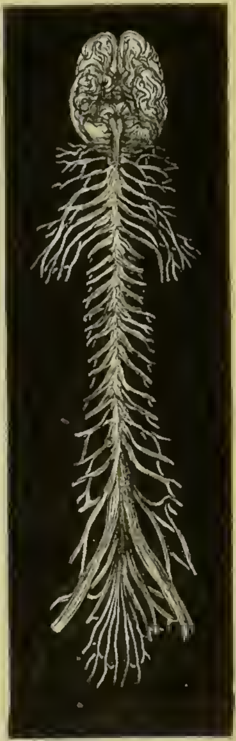
The whole of education is to fit us to do the work of life well and ably: on the one hand—the intellectual part of training; and, what is even more important, to do our work honestly and uprightly—the moral part of training. The cultivation of the brain leads, if properly conducted, to "intelligence,"—to mental power; and equally to "conscience,"—to mental rectitude and goodness; and this it achieves mainly by encouraging the development of the higher centres of the brain, which control the lower ones, from which come our impulses, or emotions.

CHAPTER V.

THE SPINAL CORD AND NERVES OF THE BODY.

FROM the brain pass fibres which go down the spinal cord to the different portions of the body. These are the "efferent," or out-bearing nerves, so called because they carry messages *from* the brain. They are also called "motor" nerves, because through these the muscles are set in motion. Up the cord to the brain pass the sensory or "afferent" nerves, which carry messages *to* the brain. These fibres constitute a large portion of the cord; which is not, however, merely a bundle of nerve-fibres, but has a certain independent power of its own, as we shall see, p. 99. Speaking broadly, the out-going or motor nerve-fibres lie in the front, the afferent fibres lying on the back surface of the cord. This cord is about 18 inches long.

From each segment or vertebra of the back-bone emerges a nerve on each side. Every one of these nerves possesses motor fibres and sensory fibres. The motor fibres pass through a hole of their own, and the sensory fibres through another hole, further back; and then they unite to form a "compound nerve." The motor fibres pass to the muscles, while the sensory fibres go to the skin over those muscles. By these sensory fibres we feel. And this sense of feeling is distributed all over the body, especially in the finger-tips. When an arm has been cut off the person may feel the little fingers still ache years after the arm has been amputated, if anything affect the nerve-fibres running to those fingers. Pressure on these sensory fibres is not felt at the spot pressed on, but in the part to which the fibres run, and where they terminate. So if the nerve-fibres which run to the little finger are cold in the stump of the arm, the little finger is still felt to ache with cold.



The motor fibres carry messages from the brain to the muscles. If there be irritation in the brain where these fibres start from, then irregular messages pass down these fibres to the muscles, which contract, accordingly, without any influence of the will. These movements, as we saw, are known as *convulsions*. Or if the motor fibres be irritated in the spinal cord, movements in the muscles to which they travel are set up—"spinal convulsions." The number of these compound spinal nerves is thirty-one.

When the cord reaches the loins it emerges from its bony canal by five branches, which come out through the *sacrum*—the broad wedge of bone at the base of the spinal column, which is wedged into the pelvic girdle. These unite to form the *sciatic nerve* on each side; which big nerve furnishes the lesser nerves for the different muscles and areas of skin belonging to the lower limbs. From its being near the skin at the hip-joint this nerve is liable to suffer from cold, and become painful: this pain is known as *sciatica.*

In the neck pass out several nerve cords, which unite to form the main nerve of each arm. Like the arteries, the main nerve divides at the knee and elbow. In the arm the "ulnar" nerve goes to the little finger and the outside of the ring-finger, while the other fingers and the thumb are supplied by another nerve. If a pea be rolled on the palm of the left hand by the middle finger laid over the long finger of the right hand, so as to be touched by the tip of the long finger and the outside of the ring-finger at the same time, two peas are distinctly felt; because messages go to the brain by two different sets of nerves. Sometimes disease involving one branch of a nerve produces pain felt in some other part of that nerve. Thus in disease of the hip-joint, so common in delicate children, the pain is felt in the knee.

But the spinal cord is not merely a bundle of nerve fibres for carrying messages to and from the brain; it has a certain power of its own. Thus if the feet are gently tickled in sleep, the legs will be moved out of the way without the sleeper necessarily being wakened. When the spine is broken by an injury, causing pressure upon the cord, then all sensation and motion is lost in the paralyzed limbs. But if these paralyzed limbs are irritated, as by pricking the soles of the feet, then the legs kick out vigorously; but the injured person does not feel the pricking, and can exercise no control over the kicking legs. There is here no conscious action whatever.

This unconscious action, as already explained, is called *reflex;* because the impression does not go to the brain, but is "reflected," at the seat of injury, from the sensory nerves to motor nerves; and so movements unconnected with consciousness are set up, or induced, by the irritation of the skin. Other instances of this "reflex" action are seen in the winking of the eyelids when anything approaches the eyes suddenly; or in the instinctive throwing up of the arm when a blow is threatened.

There is one part of the "motor" nervous system which is of great interest, and that is the part concerned with *speech.* At the top of the windpipe is placed the larynx, a sort of box. Across this stretch folds of the lining membrane known as "the vocal cords." By means of muscles attached to this box these cords can be stretched and made tight when we desire to speak. When a person sings, these cords are still more tightly stretched. This "voice" is produced by the vibrations of these vocal chords, excited by the air passing through them, and is modified by the lips and tongue into speech. In whispering there is no "voice," as the vocal cords play no part in the production of a "whisper." In disease of the larynx, or "voice-box," the persons affected lose their voice, and can only speak in a whisper.

Just as it takes a child about two years to learn to walk, so it takes it about the same time to learn to talk. At first the sound made is indistinct; then the child can say an easy word like "papa" or "mama," where there is simply a repetition of the same sound; but in time it comes to pronounce more difficult words. Then it can put different words together to express an idea, as "give me;" that is it can "talk." But like all complex movements, speech has to be acquired very slowly, and with much pains and labour

CHAPTER VI.

THE SENSES.

A CERTAIN portion of the brain, we saw, was devoted to sensation, or feeling. And it is with this portion of the brain that the sensory nerves are connected. The skin is richly supplied with nerves, so that even a needle cannot be stuck into the skin, in any part, without producing pain. Whenever a sensory nerve is injured, then pain is produced. The skin is richly supplied with sensory nerves in order that any injury to it may be accompanied by pain. By this means the textures and tissues under the skin are protected from injury. "Pain is the protector of the voiceless tissues." When a limb is cut off, pain is produced in cutting the skin ; after that the knife causes no pain as it passes through the muscles and blood-vessels beneath.

This capacity in the skin to feel pain, as well as to recognise heat or cold, or, on contact with a body, to tell whether it is hard or soft, rough or smooth, solid or a fluid, is called "touch." The finger-tips are very sensitive, so that they can distinguish minute differences in objects ; and this touch can be educated so that many persons can detect by the fingers differences which cannot be recognised by the eyes. For instance, some persons can "pair" knitting-needles, or like objects, by the touch more accurately than by the eye. By touch we can ascertain many things; and a baby must touch everything in order to "feel" and form some idea about it.

This sense of touch is not the same as that sense by which we know how heavy a thing is, or how much to "pull," as in pulling a bell, the trigger of a gun, or a rope to draw a boat. In these cases we measure the amount of muscular effort made to accomplish our object: this is known as "the muscular sense of weight."

Certain portions of the general outer sensitive area of the skin possess something more than the mere general sense of touch; they have special properties of their own, and these are called the organs of "special sense." The special senses are *sight, hearing, taste,* and *smell.*

I.—Sight.

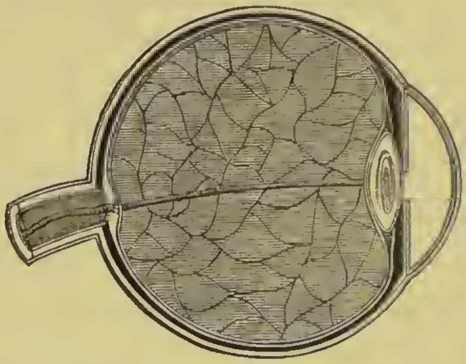
Sight, or vision, is a wonderful thing when we come to think about it. That we possess a means by which we can note things miles away from us, is a great gift. By means of a small organ which has a large nerve passing from it straight to the brain, forms, colours, and movements at a distance are brought as it were into the brain, and so into the mind. Now let us see what is the construction of this eye by which we note objects beyond our reach of feeling them.

A large nerve passes straight from the brain to the eyeball, and is spread over the interior of the firm tissues of the eyeball. If these outer tissues were not firm, the eyeball would be very liable to be burst by a blow—an accident not uncommon as it is. Moreover, this eyeball is let into a bony cavern with a ridge of bone over it, to further protect it. This ridge is covered with hair—the eyebrow, by which the eye is still more sheltered from the sun or from dripping moisture. To this eyeball little muscles are attached, by which the eye is moved about and directed anywhere, to the front or side, as the will desires. The other ends of these eye muscles are attached to the bones of the "orbit," the bony cavern in which the eyeball is placed.

The optic nerve when it penetrates the back of the eyeball expands and spreads over the interior of the eyeball. This expansion of the optic nerve is called the *retina*. When I say "interior," I do not mean the whole inside of the eyeball, but all of it except the front portion, which is surrounded by what is known as the white of the eye.

In the next illustration we see that the front of the eye projects; this is the transparent portion, known as the *cornea*. If it were not transparent, light could not penetrate to the interior of the eyeball, or reach the nerve expansion known as the "retina." When the cornea becomes inflamed, then its blood-vessels become apparent; but in health they are invisible. Running from the optic nerve to the front of the eye is the artery which supplies the interior of the eye.

Through this transparent cornea we see the coloured portion of the eye, the *iris*. This is blue at first in all creatures that are warm-blooded; but it changes in the early months of life under the effect of light to various colours; except in "albinos," who have no animal colouring matter (known as "pigment") about them, and whose irids are pink from the blood-vessels in them. This iris is a circular curtain, in the centre of which is the black hole, the "pupil."



SECTION OF THE EYE.

The iris contains muscular fibres, by the contraction and expansion of which the size of the pupil is altered. In the dark the pupil is very large, in bright light it is small. It is large in the dark, to admit as much light as possible into the cavity of the eye; in bright light it is small, so as to cut off the light when too great for the sensitive retina. In cats, when basking in the sun, the pupil is only visible as a thin line; when they are in the dark the pupil opens out, and then they have a remarkable power of sight.

In order to absorb surplus light, the retina is covered with a layer of dark pigment called the *choroid* coat, and this it is which makes the pupil "black." It extends into the iris, and thus gives the colour to the eye. By such means, then, the amount of light going to the eye is regulated.

But there are still more beautiful arrangements in the eye. The coloured iris stands in front of a small oval body known as the *crystaline lens.* This is a very important little body, as, when it becomes opaque, blindness follows. Betwixt this and the iris, and betwixt the iris and the cornea, is a watery fluid; and this chamber is known as the "anterior chamber" of the eye. Behind the lens is the *vitreous humour*, a jelly-like substance. By these different arrangements the rays of light are made so to fall on the retina that things are "visible," and also seen clearly.

The strong outer coat of the eye is called the *sclerotic* (*scleros*, the Greek for "hard"). This strong outer coating protects the delicate internal structures of the eye from injury, and also keeps them in their places.

The eye possesses the power of accommodating itself to distance, *i.e.* of seeing things close to, or far away: some birds have a little ring of bony plates at the union of the cornea and the sclerotic, which enables the form of the cornea to be so altered that they can see distinctly objects at a great distance. Some persons can see well things close to, but not those at a distance; while others can distinguish distant objects, but cannot see distinctly what is near the eye. Such persons have to wear spectacles adapted to their sight.

In other cases, common in children, the two eyes are not perfectly alike, and then headache is produced by reading. Here by means of spectacles with different lenses, the sight of the eyes is made alike; and then the child can read and study without producing headache. Headache here is due to "straining" the eyes to make them work together; just as we have to "strain" the eye to distinguish small movable objects.

We cannot see things near to and far off at one and the same time. When we look through iron railings at a house at some distance beyond, if we see the house distinctly, we do not see the railings clearly; if we look chiefly at the railings, we do not see the house distinctly.

To protect the eyes from light we possess movable shutters, the eyelids. When the light is very bright we partially close them; while their complete closure is generally necessary to sleep. The free edges of these shutters are fringed with fine hairs, the eyelashes. These shade the eye from light and protect it from fine particles, which would otherwise readily enter the eye. The movable eyelids close or wink *reflexly*, and without waiting for the will, when anything threatens the eye.

Besides being an organ of special sense, the eye possesses expression ; and the " look " varies wonderfully with the states of the mind, and the eye can be made to " speak " eloquently at times, as most children know right well.

II.—**Hearing.**

Another means of knowing something of matters far away, as well as near, is furnished by the organ of hearing. The vibrations of air produced, as, for instance, by a waterfall, are conveyed, by means of the mechanism of the ear, to the brain as sound.

The ear consists of an outer and an inner, or an " external " and " internal " ear. Animals prick up their ears in order to hear more distinctly ; and so do the Red Indians, who can throw their ears out, and so collect the vibrations of air into the canal of the ear. On the same principle deaf persons put up their ear-trumpet, when they wish to hear what is said. A few persons among ourselves can " wag " their ears ; but with most people the ear is immovable, though the muscles for moving it are quite distinct under the skin.

The ear itself, the internal hearing organ, is placed in a portion of the side bones of the head ;

and this portion of the skull in which the ear-cavity is placed is so hard that it is termed "the *petrous* portion of the temporal bone" (*petros* is the Greek for "stone"). In this cavity are placed certain little bones which constitute an interesting portion of the mechanism of hearing.

The canal leading to the internal ear has a membrane stretched across it, known as "the drum of the ear." To the inside of this is attached the shaft of a hammer-shaped little bone, the *malleus* (Latin for hammer). The head end of the hammer is jointed to another little bone, the *incus* (anvil), which bears at its point a smaller little bone called the *stapes*, or stirrup, because of its close resemblance in shape to a stirrup.

By means of these "ossicles" (tiny bones) the vibrations of the drum of the ear, set up by vibrations of the outside air, are communicated to the fluid in the canals of the internal ear; and the motion of this fluid is conveyed by the nerve of hearing to the brain as sound. The mechanism of the internal ear is very fine; and the old practice of boxing the ears of refractory pupils often led to permanent deafness, and so has properly been abandoned.

The middle ear communicates with the throat by a narrow canal known as the *Eustachian tube;* by this means the atmospheric pressure on the drum of the ear is equalised on each side. When this tube is closed by a cold and sore throat, then deafness follows; and hearing only returns when this tube is once more cleared. Throat-deafness is quite common.

Deafness may be due to changes in the outer ear, and then the vibrations of a tuning-fork can be heard by applying the fork to the teeth; the sound, *i.e.* the vibrations, are thence conveyed to the internal ear through the bones of the head.

When persons become blind, their hearing becomes very acute. People hear very differently; some acutely, others are "dull of hearing." The chirp of the grasshopper is inaudible to many; while some musical people can detect the faintest difference in a note. The highest musical sound is produced by vibrations of 32,000 to the second; the lowest by vibrations of about 32 per second. Vibrations of a string or tuning-fork can be heard long after the eye has ceased to be able to note them.

III.—**Taste.**

Taste is situated in the mouth, and especially in the tongue. The tongue is useful in rolling food about in the mouth in the act of mastication; and also is useful in speaking. In both these uses the tip is the most active part of the tongue. In taste, however, the tip is less delicate than the thicker portion of the tongue. The nerves of taste are most sensitive at the base of the tongue.

The tongue is really a muscle on whose surface are *papillæ* (from *papilla*, the Latin for "a little eminence"); these have in them sensitive nerve fibres, and the impression made by the different substances we take into the mouth upon these nerve fibrils gives what is known as "taste." Some fluid is requisite for the production of taste, and so the tongue is kept moist. Attractive articles of food excite in these glands a flow of saliva; and so we say of them they "make the mouth water." Acrid or sapid articles of food produce a free flow of saliva.

This taste is much more acute in some persons than in others. It is highly developed, for instance, in tea-tasters and wine-fanciers. When taste is blended with smell we get the sensation known as "flavour." Flavouring agents are added to plain articles of food to render them more attractive to the palate; and sugar, in the form of "sweeties" of some sort, has charms for almost every child.

IV.—Smell.

The sense of smell is located in the air-passages of the cavity of the nose, in their lining membrane. When we wish to smell, we draw the alæ of the nostrils near the *septum* which divides the two nostrils, and inspire, so as to direct the air out of its ordinary track, and throw it more against the parts where the sense of smell is most distinct. By so doing we can perceive clearly smells and odours scarcely appreciable in the ordinary act of breathing.

The sense of smell varies much with individuals; in some persons the sense is very dull, while others have "a very sharp nose." The chief utility of smell is to guard us against unhealthy effluvia. The stench is not itself the danger; but it stands to it in the same relation that the rattle of the rattle-snake does to its fangs; when you hear the rattle, you know the fangs are not far distant. So bad smells tell of a state of matters where disease is not far away.

Some of the odours of plants are exceedingly pleasant; and scents and perfumes are much patronised by ladies. The sense of smell is soon blunted; and people who live among evil-smelling places, as tanneries, for instance, soon cease to observe the smell. In most animals the sense of smell is much more acute than in man. The dog follows the footsteps of his master by the sense of smell; so do foxhounds trace the fox; and the bloodhound has been used to hunt runaways—especially when slavery existed.

V.—Touch.

The general sensation of pain, heat, &c., possessed by the skin is very highly developed in the tips of the fingers. Any one who will look carefully at the skin of the palm of the hand, and the inner surface of the finger or thumb, will see that the skin is in tiny furrows. At the tips of the fingers these furrows form circles, growing larger and larger. If the finger-tip be smeared with a coloured fluid, as ink or blood, an impression can be made on paper like an engraving, showing these widening circles. In these furrows are nerve fibrils, which are exquisitely sensitive. By this keen sense of touch the hand of the craftsman acquires its skill; and the finer the sense of touch the greater becomes the manual skill.

The roughness or smoothness of a surface; the sense of hardness or softness; of heat or cold; the character of a fluid: are revealed to us by the sense of touch, in the finger-tips especially.

By the education of the special senses they can be highly developed, and the "trained eye" can readily detect what is almost invisible to the untrained eye. The touch of certain workmen becomes exquisitely delicate; while "skilled" labour can command a much higher price than is attainable by "unskilled" labour. At the present day the battle of life is chiefly fought with the nervous system, and its culture commences in learning to walk and talk; while school training is but a preparation for the serious brain-work of adult life.

THE END.

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